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U.S. DEPARTMENT OF AGRICULTURE
Department Bulletin
1250-1349

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UNITED STATES DEPARTMENT OF AGRICULTURE



DEPARTMENT BULLETIN No. 1267



Washington, D. C.

October 14, 1924

THE ROUGH-HEADED CORN STALK-BEETLE¹

By W. J. PHILLIPS, *Entomologist*, and HENRY FOX,² *Entomological Assistant*,
Cereal and Forage Insect Investigations, Bureau of Entomology

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INTRODUCTION

The ravages of (*Ligyrus*) *Euethela rugiceps* (Lec.) were first brought to the attention of the writers in 1914 (9, p. 3).³ Dr. J. M. Gouldin, of Tappahannock, Essex County, Va., in a letter dated June 26, 1914, stated that some farmers lost nearly their entire corn crop. The late Prof. F. M. Webster, then in charge of Cereal and Forage Insect Investigations, instructed the senior writer to make a personal survey of the situation. This was done early in July, 1914, and showed that serious damage (Pl I, A) had occurred on several hundred acres of corn in the vicinity of Tappahannock, Va. At that time the beetles had practically ceased their activities, but specimens were sent to Charlottesville, Va., for life-history studies. Since little was known of the habits of this pest or the means of control, the problem of determining these points was assigned to the Charlottesville laboratory, with the senior writer in charge.

The breeding records obtained from material secured in 1914 were disappointing, and since the locality of the outbreak was rather

¹ *Euethela rugiceps* (Lec.) ; order Coleoptera, family Scarabaeidae.

² Resigned August 31, 1918.

³ Reference is made by number (*italic*) to "Literature cited," p. 33.

inaccessible, temporary headquarters were established in the heart of the infested district, in order to study the problem at first hand. In the spring of 1915 the junior writer was assigned to Tappahannock, where he remained until October. In the meantime detailed studies were being conducted in breeding cages at Charlottesville as a check on the work at Tappahannock. The junior writer returned to Tappahannock in 1916 to complete the data on the life history and to start field experiments for controlling the pest, the results of which have already been published in brief (9). In this publication it was termed the "rough-headed corn stalk-beetle," a translation of the specific name which seems more appropriate than its earlier name of "sugar-cane beetle," since the insect has been receiving constantly growing emphasis as a corn pest.

ECONOMIC HISTORY

Euetheola rugiceps (Pl. II, A) was first named and described by John Le Conte (8) in 1856 from specimens obtained in Georgia, and was for a number of years thereafter considered a rather rare southern insect. Riley (10) and Comstock (2) published the first records of the depredations of this pest in 1880, when it first attracted their attention as a sugar-cane insect on the plantations in Louisiana. Comstock stated that the planters in the infested district claimed to have known the pest and had recognized it as a serious menace to sugar cane for a period of about 20 years preceding the outbreak in the seventies. According to the planters, the first serious outbreak occurred about 1855 or 1856; the next destructive one was in 1875. During 1875 and the two succeeding years the depredations on the sugar-cane plantations caused serious alarm, but there seems to have been a decrease in the activities of the insect in 1879. In 1880 the beetles reappeared and inflicted serious loss. This outbreak was reported by Comstock (3). Although both Riley and Comstock incidentally recorded the insect as injuring corn, it was considered primarily a sugar-cane pest and received the vernacular name of "sugar-cane beetle," and by this term it has been designated in the literature until recently. L. O. Howard (?) in 1888 was the first to recognize *E. rugiceps* as a corn pest, publishing in that year an account of its depredations to corn in North Carolina and Mississippi. About the same time F. M. Webster (14) made similar observations in Arkansas and Louisiana. In 1895 Weed (15, 16) reported losses to corn growers in Mississippi, but, through what was evidently an error in identification, attributed the damage to *Ligyris gibbosus* which it is now believed never injures corn. Since then depredations by this pest have been reported at rather frequent intervals by an increasing number of investigators, among whom may be mentioned Titus (13), Garman (6), and Sherman (11), the last-mentioned author especially having published an interesting account of the beetle and its work in North Carolina.

The earliest record of injury to corn in Virginia was in 1913, when several farmers reported injury in the "tidewater" section of the State. In the following year the depredations were most severe.

DISTRIBUTION

The known distribution of *Euetheola rugiceps* in the United States is shown in Figure 1. The data upon which the map is based were obtained from the literature, from hitherto unpublished field records and correspondence of the bureau, and from personal correspondence with a number of museum and experiment station entomologists.⁴

Euetheola rugiceps is recorded from all the Southern States lying south of the latitude of Washington, D. C., with the exception of Florida and Oklahoma. Judging by the erratic manner in which the species has been observed to occur in the infested sections of Virginia, it would be inadvisable to draw final conclusions regarding the limits of distribution from the evidence at present available. In Virginia the species was found only in that part of the coastal plain which lies between the Potomac and James Rivers, apparently preferring low, moist, poorly drained soils. Even within the area thus restricted, the species appears at present to be of very unequal distribution, being abundant in certain localities and rare or absent in others. It may be found swarming in certain fields, utterly destroying the corn crop, while other fields of the same general type less than a mile away appear to be uninfested. Doubtless there are unknown factors which influence and limit the spread of this species.

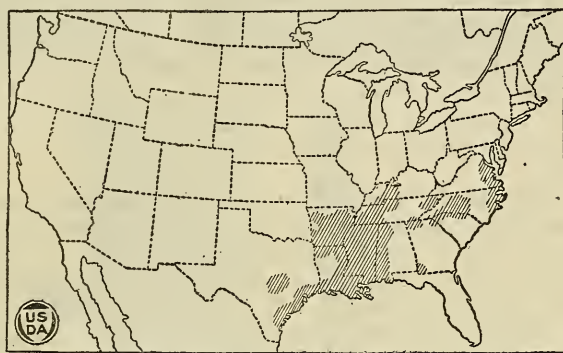


FIG. 1.—Map showing distribution of *Euetheola rugiceps* in the United States

The following is a list of localities, arranged according to States, from which there are records of the occurrence of the species.

Alabama.—Birmingham, Catherine, Carrollton, Cleveland, Eutaw, Hampden, Hartsells, Mobile, Sprott.

Arkansas (by counties).—Ashley, Bradley, Clark, Crawford, Cross, Hot Springs, Howard, Jackson, Jefferson, Lincoln, Lonoke, Monroe, Nevada, Perry, Pope, Pulaski, St. Francis.

Georgia.—Bainbridge, Canton, Dalton, Macon.

Kentucky.—Guthrie and Hartford.

Louisiana.—Atchafalaya River, Baldwin, Baton Rouge, Berwick, Breaux Bridge, Broussard, Castille, Clinton, Church Point, Crowley, Donaldsonville, Franklin, Hester, Koran, La Fayette, Mer Rouge, Mill Haven, Monroe, Mound, Morgan City, New Iberia, New Orleans, Oak Grove, Plaquemine, Rayne, Scott, St. James, St. Joseph, Tensas Parish, Ville Platte.

⁴ Those who furnished valuable data in this connection include Franklin Sherman, North Carolina Department of Agriculture; J. R. Watson, Florida Agricultural Experiment Station; A. F. Conradi, Clemson College, S. C.; W. V. Reed, Georgia State Board of Agriculture; W. E. Hinds, Alabama Agricultural Experiment Station; J. J. Davis and George G. Ainslie, of the Bureau of Entomology; S. J. Hunter, of the University of Kansas; W. J. Holland, Carnegie Museum; Charles Schaffer, Brooklyn Institute of Arts and Sciences; G. G. Becker, Arkansas Agricultural Experiment Station; H. Garman, Kentucky Agricultural Experiment Station.

Mississippi.—Agricultural College, Brookhaven, Canton, Durant, Greenwood, Gulfport, Kosciusko, Natchez, Ocean Springs, Winona.

North Carolina.—Bostic, Gastonia, Greenville, Monroe, Mount Pleasant, Pantego.

South Carolina.—Cheraw, Union.

Tennessee.—Clarksville, Greeneville, Milan, Savannah, Sevierville.

Texas.—Austin, Beaumont, Fedor, Galveston, Jackson County, New Braunfels, Port Arthur, Victoria.

Virginia.—Achilles, Coles Point, Kinsale, Naxera, Odd, Sharps, Tappahannock.

LIFE HISTORY

GENERAL ACCOUNT

Euethoeola rugiceps hibernates in the soil as an adult in or near its normal feeding grounds. It reappears with warm weather, which in Virginia is in late April or early May. At Tappahannock, Va., the earliest dates on which the beetles were found abroad were April 23, 1915, and May 1, 1916. The exact time of their appearance is unquestionably determined by the prevailing weather conditions, being accelerated by high temperatures and retarded by low ones. Thus far the beetles have been found flying only at night, when they are frequently attracted to lights, but it is not an uncommon occurrence to find them crawling upon the surface of the ground in daylight.

The adults begin to feed as soon as they leave their hibernating quarters. Their normal food evidently consists of certain grasses, particularly those belonging to the genus *Paspalum*, but should these plants be scarce they readily turn their attention to corn, if any fields be near.

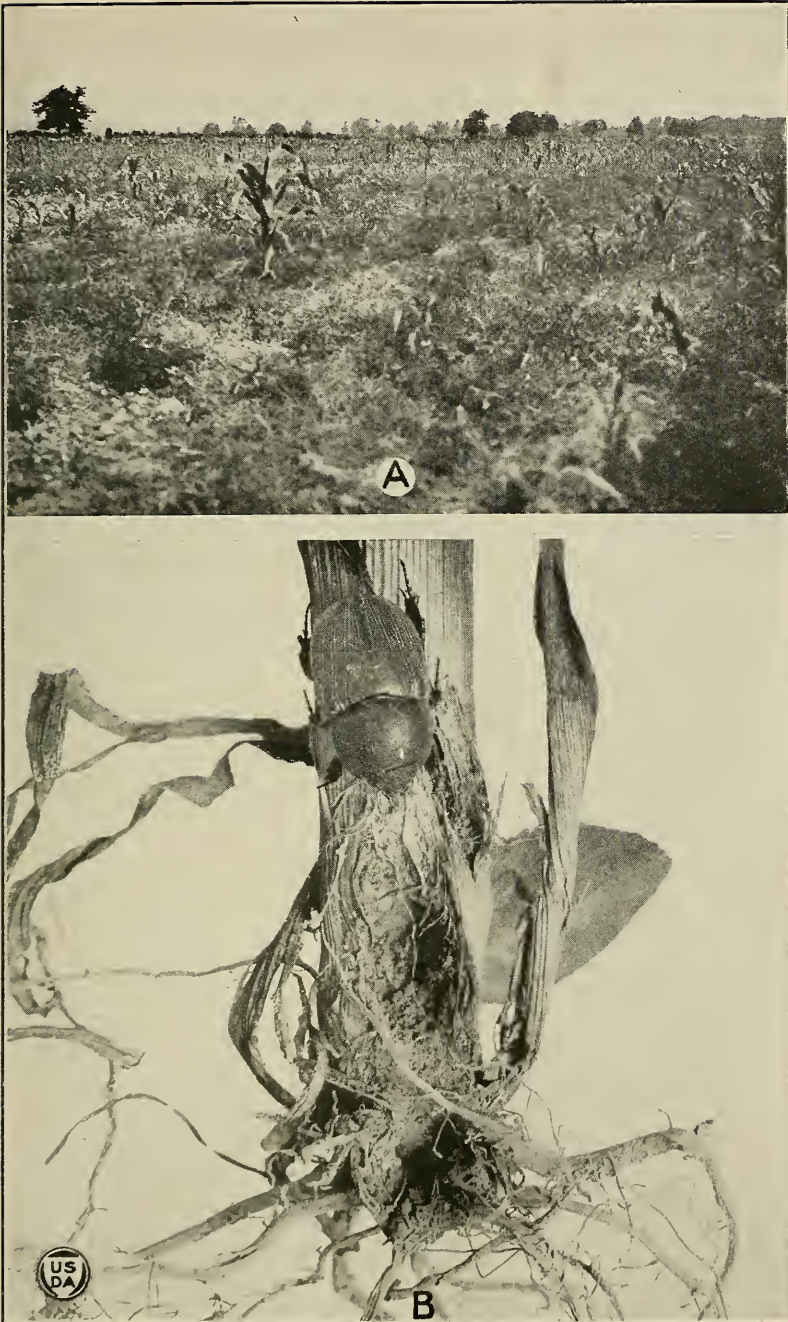
Mating apparently occurs considerably in advance of egg-laying, though it also undoubtedly continues throughout the season of greatest activity, since pairs have been observed *in coitu* after the egg-laying season was well advanced.

Oviposition was observed at Tappahannock chiefly during June, the earliest eggs being found on June 5. The beetles deposit their eggs a few inches below the surface of the ground wherever they happen to be feeding. It therefore appears that this insect spends practically its entire existence below ground. The beetles feed, mate, and oviposit, and the larvæ complete their development below ground.

Under ordinary summer conditions the eggs require from two to three weeks to hatch. When first hatched the larvæ measure about 3 millimeters and when full grown about 32 millimeters or $1\frac{1}{4}$ inches. The larvæ require from six to eight weeks to reach maturity at Tappahannock, Va. Full-grown larvæ were found from August 2 to October 2, but were most abundant the last week in August and the first week in September. The pupa stage lasts about two weeks under normal weather conditions. The first pupa found in the field at Tappahannock was August 16 in 1915 and August 12 in 1916. The latest field record was November 2, 1916.

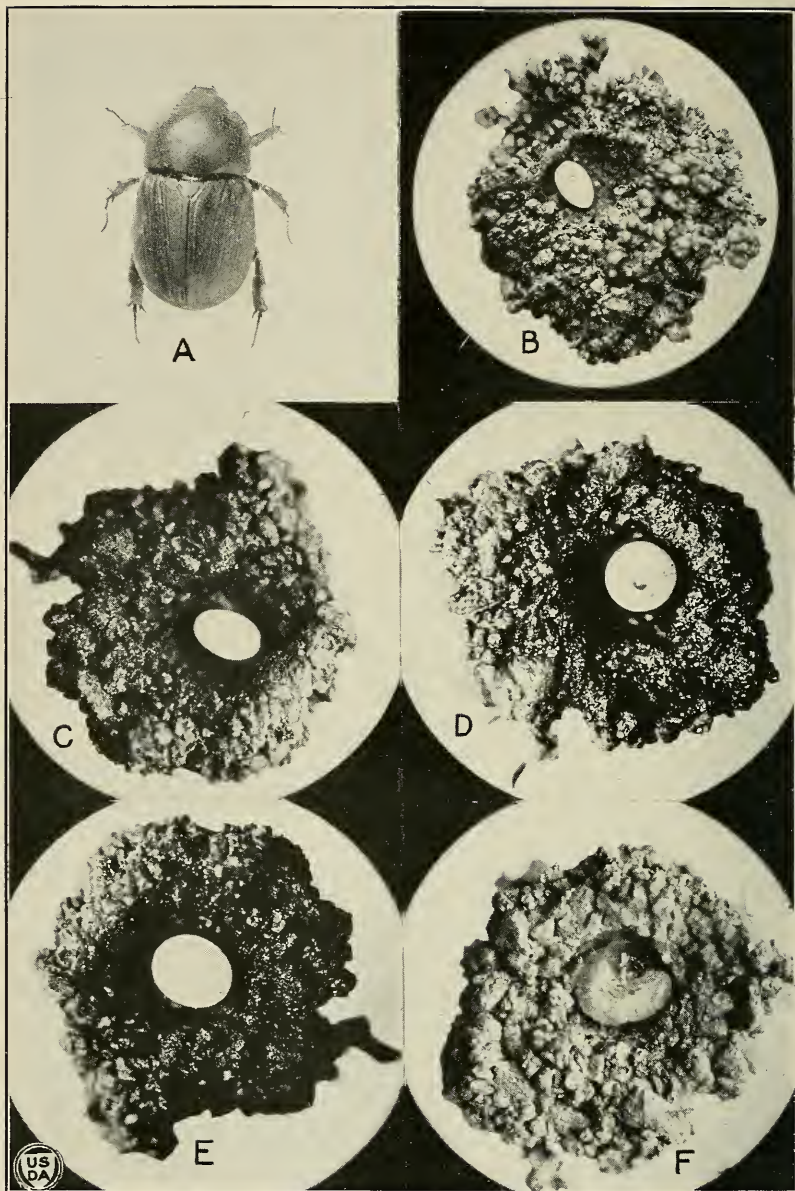
The majority of the old beetles die or disappear in midsummer; some stragglers, however, nearly always overlap the new generation. Such stragglers may be easily distinguished by their dull, opaque black, the new ones being highly polished.

Adults of the new generation were found at Tappahannock as early as August 24, but the majority appear during the last half of



THE ROUGH-HEADED CORN STALK-BEETLE

A, Cornfield at Tappahannock, Va., badly damaged by the rough-headed corn stalk-beetle (*Euthoea rugiceps*) (photograph by W. J. Phillips); B, corn plant showing typical injury from adult of *E. rugiceps* (photograph by J. H. Paine)



THE ROUGH-HEADED CORN STALK-BEETLE

A, Adult; *B*, egg when first deposited, inclosed within a ball of earth, the latter broken open to show egg within; *C*, egg when development has begun; *D*, end view of egg just before hatching (the dark area is the mandible of the larva showing through the eggshell); *E*, lateral view of egg just before hatching; *F*, larva shortly after hatching. (*A*, photographed by J. H. Paine; *B-F*, by W. J. Phillips)

September. The new generation of beetles do not appear to be very active, remaining usually where they emerge, though they have been found soon after emergence feeding upon the culms of *Juncus effusus* and certain grasses of the genus *Paspalum*.

EGG

DESCRIPTION

The egg when first laid is oblong, pure white, and perfectly smooth (Pl. II, *B*). Subsequently the egg enlarges until it is nearly double its original size and changes its form until almost globular (Pl. II, *B*, *C*, *D*, and *E*). Eggs measured by the senior writer averaged about 2 millimeters in length and 1.5 millimeters in diameter. These were several days old and approximately full size. No measurements of freshly deposited eggs were made.

METHODS OF COLLECTING AND INCUBATING

A small number of the eggs used in the investigations were gathered in the field, but the greater number were obtained from the breeding cages.

In the field the eggs were found in the ground, where it was usually possible to obtain them by digging.

To obtain eggs which were known with certainty to belong to the present species, adult beetles were confined in suitable breeding cages, from which the eggs were gathered at regular intervals. Each cage consisted of a 12-inch standard-size flowerpot filled with finely-sifted soil and covered with a cylindrical wire-screen top; the whole outfit had essentially the same form and arrangement as that portrayed by Davis (5, *pl. 3, fig. 4*). The soil in these cages was kept moderately moist, and at intervals, varying from a few days to a week and a half, was passed through a fine-mesh sieve. The meshes in this were fine enough to retain the eggs, which were then transferred to the incubating boxes.

In the breeding cages the beetles were first fed by transplanting young corn plants to the cages, but as the labor of replacing the food plants every few days proved burdensome, a handful or so of corn kernels was buried in the soil. These proved to be a highly satisfactory substitute, the beetles feeding upon them as readily as upon the living plant.

The receptacles used in incubating the eggs were rectangular tin boxes like those used by Davis for the same purpose (5, *pl. 4, fig. 7*). These boxes were about three-fourths filled with finely-sifted earth, which was kept to the right degree of moisture by occasionally adding a few drops of water with a pipette. As the eggs were transferred to a box each was placed in a small pit made with the blunt end of a pencil, and as the boxes were filled the lid was replaced and they were then kept in the shade. Usually the lid would so conserve the moisture originally in the soil that in most instances it was unnecessary to add more water during the period of incubation.

PLACE OF DEPOSITION

The eggs are deposited in the ground, and apparently the females exercise no particular care in the choice of a place in which to

leave their eggs. As the beetles themselves require a certain degree of moisture in their surroundings, they avoid very dry situations at all times. Naturally the eggs are most frequently encountered in places to which the beetles resort for the purpose of feeding. For this reason they are most numerous in infested cornfields, and in old pastures and grassy waste lands which constitute the normal habitat of the species. Field observations indicate that cornfields, especially if they happen to be well drained and are kept in a good state of cultivation, are generally very unfavorable situations for the subsequent development of the larvæ; for, although eggs are laid abundantly in corn hills, well-grown larvæ were rarely found in the same fields later in the season. This may be plausibly accounted for by the fact that the soil in well cultivated cornfields during periods of high temperature and drought is unsuitable for the development of the larvæ.

MANNER OF DEPOSITION

The process of oviposition has not been observed. In most instances it appears that the eggs are deposited singly, although occasionally several may be found within a space an inch square. They are rarely inclosed in a clearly defined ball of earth. Possibly this may be due to the rather incoherent nature of the soils in which eggs were obtained in Virginia. At Charlottesville some experiments were conducted to ascertain whether the beetles were capable of forming such balls of earth by varying the moisture content of the soil and by adding clay to it. As a result a number of more or less firm balls were obtained, each inclosing a cavity containing a single egg (Pl. II, *B, C, D, E*), but the greater number of eggs were left loose in the soil, apparently with no attempt on the part of the beetles to inclose them in a ball of earth. All the earth balls obtained were found in soil that had been fairly well saturated with water. This circumstance would indicate that the particles of which the earth balls are composed are held together only by the cohesive tenacity of the clay, and not by a glutinous secretion of the beetle.

NUMBER DEPOSITED

The number of eggs one female is capable of depositing under natural conditions is difficult to ascertain directly, but some experiments conducted at Charlottesville in 1915 provide data which with a certain degree of reservation may be used as the basis for an estimate. These data indicate that the average deposition for each individual may vary from no eggs to rather more than three a day. Part of this variation may be accounted for by fluctuation of temperature. It has been repeatedly observed that high temperatures favor deposition, while low temperatures retard it. A part of the variation may also be attributed to the disturbance incidental to an examination for eggs.

Usually the average rate of egg production for each individual varies, under particular summer conditions, from 1 egg in every 4 days to 2 eggs a day; and it has been found that a similar range of variation in average daily production occurs if the figures are computed on the basis of a longer period, such as a month (or its equiv-

alent in days), provided that no months later than September are taken into consideration.

From these results it would appear to be a fair inference that on the average each female, under conditions similar to those existing in the experimental cages, is capable of depositing an egg every day during the normal breeding season. If the season lasts between one and two months, a beetle during this period ordinarily may deposit from 30 to 60 eggs.

GROWTH

As previously stated, the egg after deposition enlarges until it is nearly or quite double its original size, and simultaneously changes its form until it is almost globular (Pl. II, *B-E*). Eggs measured at Charlottesville several days after deposition averaged about 2 millimeters in length and 1.5 millimeters in diameter. Unfortunately no measurements of freshly laid eggs were made, but the weights of eggs in different stages of growth were determined with the following results:

In one lot of 15 eggs, all weighed within less than 48 hours after being deposited, a total weight of 0.02013 gram was obtained, an average of 0.001342 gram for each egg. Three days later this same lot weighed 0.04041 gram, an average of 0.002694 for each egg, practically twice the original weight. It was noted that one egg of this lot, on the second weighing, had not increased in size, possibly not having been fertilized, so that the average weight of an egg, at this time, was doubtless somewhat greater than the figures given indicate.

In a second batch of 15 eggs, weighed when they were between 10 and 11 days old, the total weight obtained was 0.05052 gram, an average of 0.003368 gram for each egg, or approximately $2\frac{1}{2}$ times the average of an egg when deposited.

In a third batch, consisting of 9 eggs estimated as 16 days old and nearly ready to hatch and 6 others which were at least 12 days old, the total weight obtained was 0.06538 gram, an average of 0.004359 gram for each egg, or approximately $3\frac{1}{2}$ times the weight of a freshly deposited egg.

No attempt was made to ascertain the cause of this increase in size and weight of the egg by determining its dry weight, but it is doubtless due to the absorption of water by the egg from the surrounding soil. The fact that the dead egg referred to above had not perceptibly increased in bulk after remaining in the soil for three days indicates that only the living eggs are capable of absorbing water.

MOISTURE REQUIREMENTS

It appears evident, as intimated in the preceding section, that the presence of a certain amount of available moisture in the soil is an essential prerequisite for development. The point was tested experimentally at Charlottesville, and it was learned that the eggs perish if kept in dry soil.

It is to be regretted that no quantitative determinations of the moisture requirements of the eggs were made, as these would have been of value in explaining the conditions under which the species

occurs in nature. The experience of the writers, however, both in the field and in experiments, indicates that an excess of moisture is almost as unfavorable for the eggs as a deficiency. The places in which the species normally occurs and in which it breeds most abundantly are so situated with reference to local drainage conditions that, although the ground retains a constant supply of available moisture, it is never saturated with water for any considerable period of time during summer. It is doubtless these moisture requirements which underlie the marked tendency of the species to congregate in the lowlands bordering marshes and drainways and to be limited on the higher ground to local sunken areas in which the soil is rather slowly drained.

INCUBATION

Experiments on the duration of the period of incubation were conducted at Charlottesville. Owing to conditions attending the work, it was rarely possible to determine the precise time at which an egg had been deposited, and, for this reason, the results obtained are at best but approximations. On one occasion (July 26) a female was found in the act of depositing an egg. On August 9 this egg hatched, giving an incubation period of 14 days.

There may be considerable variation in the time required for incubation. This may be accounted for by variations of temperatures, high temperatures accelerating and low ones retarding development. As a rule, the period of incubation under favorable midsummer conditions varies from two to three weeks. In the fall this time is greatly extended, extremes of from 35 to 50 days being reached in October and November. All eggs which had failed to hatch by the middle of November were buried in their containers in the ground and there kept over winter. In early April they were dug up and examined, but in all instances the eggs were dead.

HATCHING

The chitinized larval jaws may be seen through the translucent egg membrane (Pl. II, *D*) several days before hatching takes place. When hatching occurs, the egg membrane appears to collapse and to split at a point close to the dorsal surface of the larva. In one instance the rupture of the membrane occurred in the vicinity of the thoracic region; in another at about the level of the third abdominal segment. It evidently results from the contortions of the inclosed larva in an effort to free itself. After the membrane has split the larva continues its efforts, bending and extending its body at frequent intervals until it has finally managed to extricate itself, though occasionally portions of the membrane may adhere to the larva for a considerable time after hatching. In no instance did the larvæ make any attempt to devour the egg membrane.

The time consumed in the process of hatching was in one instance 7 minutes, in another 35 minutes. Plate II, *F*, shows the newly hatched larva and Figure 3 shows the relative size of the head and body immediately after hatching.

LARVA

DESCRIPTION

The full-grown larva of *Euethola rugiceps* (fig. 2.) is a robust, thick-bodied grub, with an approximate length of 32 millimeters ($1\frac{1}{4}$ inches) and an average thickness of about 6 millimeters. It is nearly pure white, deepening posteriorly to a dark gray or brownish tint, due to the dark color of the viscera appearing through the transparent cuticle; the legs are yellowish amber; the spiracles orange; the head shield a distinctly reddish hue, closely approximating a bright shade of Indian red. In alcoholic specimens these colors are invariably much obscured.

The most distinctive morphological features of the larvæ are found in the head shield and the last ventral segment. The head shield (Pl. III, A) is distinctly, even coarsely punctate, the punctures being especially coarse and dense on the portion immediately above the clypeus.

The last ventral segment of the larva (Pl. III, D) bears a somewhat irregular, median, double row of modified bristles, each having the appearance of a denticle or minute spine. In the possession of this feature the larva of *Euethola rugiceps* is unique, so far as the writers are aware, among the Dynastini and agrees with the larvæ of the genera *Phyllophaga* and *Anomala*, though in these the corresponding character is much more regular and clearly defined than in *Euethola* (Pl. III, D-G). In all other respects it resembles the type of larva normal to the Dynastini.



FIG. 2.—Full-grown larva of *Euethola rugiceps*. Note relative size of head and trunk. (Drawn by W. R. Walton)



FIG. 3.—Young larva of *Euethola rugiceps* immediately after hatching. Note relative size of head and trunk, in comparison with Fig. 2. (Drawn by W. R. Walton)

METHODS OF COLLECTING AND REARING

Owing to the pugnacious habits of the larvæ it is best to place each in a separate receptacle when collecting, also to place a little vegetable mold or fine soil in the box to prevent the larva from rolling about and being injured.

Attempts were made to rear the larvæ in flowerpot cages, similar to those used to confine the beetles, but the results were disappointing.

The failures were perhaps due, in part, to the fact that suitable food was not supplied the young larvæ when the cages were started, as the food requirements of the young larvæ were then very imperfectly known; possibly, also, to inability to protect the larvæ against certain of their enemies. Ants frequently invaded the cages, and, as they are known to attack and kill the larvæ, were doubtless responsible in some measure for the unsatisfactory results obtained. The

larvæ are often infested with certain mites, which are decidedly injurious to them and frequently cause their death. During the season of 1915 these mites were so abundant and widely distributed that it was found necessary to fumigate all samples of soil used in the breeding boxes.

The salve-box method of rearing larvæ recommended by Davis (5, p. 138) gave the best results and proved entirely satisfactory, once the peculiar needs of the young larvæ were ascertained. The principal difficulties were to provide them with an adequate supply of suitable food and to protect them from mites and disease fungi. A few grains of wheat or corn were added to the boxes containing the young larvæ, but the larvæ made no attempt to feed upon either the grain itself or the plantlet issuing from it. Scarcely better results attended the use of the different kinds of manure, either fresh or old and thoroughly weathered. The fine, fibrous rootlets of the corn plant were also tried, but without success. Finally, a satisfactory food was found in a well disintegrated, brownish plant residuum, or vegetable mold, a thin layer of which occurred frequently in an old pasture at Tappahannock, where the species bred abundantly. At first this material was gathered beneath tussocks of the common rush (*Juncus effusus*) where it consisted of the broken and decayed culms of this plant, but subsequently was obtained with much less difficulty in connection with certain grasses belonging to the genus *Paspalum* and with Japan clover. It was the original intention to utilize this material, owing to its softness, merely as a medium in which the young and tender larvæ might be kept with the least chance of suffering injury. At first a grain or two of wheat was added to each of the boxes containing this material, but it was soon noticed that the wheat was left untouched, whereas the vegetable mold decreased rapidly in amount as the larvæ grew and was replaced by excrement. The wheat kernels were thereafter omitted and finely sifted vegetable mold alone used with entire success.

A larva, after emerging from the egg, was carefully removed to a small tin salve box previously half filled with a quantity of the vegetable mold, finely sifted and slightly moistened. The young larva would invariably burrow into the mold and excavate for itself an irregular cavity, or cell, and there feed upon the surrounding material. When this had been consumed, the larva was temporarily removed from the box, the feces and other wastes cleaned out, and a fresh supply of mold added.

As the larvæ grew, the amount of mold consumed by them increased rapidly, necessitating frequent replenishing. The plan was adopted of substituting for the vegetable mold a kernel or two of corn, previously softened by soaking in water overnight. With larvæ from half-grown to full-grown this proved to be a satisfactory substitute for the mold, and greatly lessened the work of caring for them. Fresh kernels were added only when the old ones had been almost consumed.

Considerable difficulty was experienced in protecting the larvæ from the minute mites previously referred to, specimens of which were identified by Nathan Banks as the hypopus stage of *Rhizoglyphus phyloxerae* Riley. During the season of 1915 this pest was

extremely troublesome, and it required the utmost vigilance to prevent its gaining access to the breeding boxes. According to Mr. Banks, the mites are saprophytic upon decaying vegetable matter, but whatever may be their normal feeding habits, it is the uniform experience of the writers, as well as of others who have worked with white grubs, that the presence of these mites in the breeding boxes is highly detrimental to the larvæ. All soil or vegetable mold for use in breeding boxes was thoroughly fumigated with chloroform to kill all mites. Boxes infested with mites were emptied and sterilized in boiling water. To remove the mites from the larvæ the latter were gently, but firmly, held between the thumb and index finger of the left hand and the mites loosened and brushed off under a binocular by means of forceps. Sometimes, to facilitate the removal of the mites, the larvæ were plunged for an instant into a very weak solution of formaldehyde and then quickly washed in tap water. This treatment appeared to cause the mites to adhere less tenaciously to their host, and also had a quieting effect upon the larva.

For some reason—possibly the prevailing low temperatures of the season—these and other species of mites appeared to be unusually scarce in 1916, so that during that year these precautions were found unnecessary.

FOOD AND FEEDING HABITS

The experience of the writers both in the laboratory and in the field indicates that the normal food of the larvæ consists chiefly of decayed and disintegrated vegetable matter. This vegetable mold does not usually occur as a distinct layer, being intimately intermixed with the surface soil; but in the particular pasture of Tappahannock where most of the collecting was done the mold had accumulated as a practically pure layer on the surface wherever the plant cover was sufficiently dense to protect it from wind and from the trampling of stock. This would be particularly true of old pastures that had not been tilled for a number of years. Vegetable mold of the finest consistency usually occurred under the low, matlike growths of Japan clover (*Lespedeza striata*), wherever these were dense enough to afford it adequate protection. In the layer of vegetable mold, or in the soil immediately underlying it, larvæ of *Euetheola rugiceps* in all stages of growth were found in abundance, particularly where it was associated with clumps of *Paspalum*, a circumstance that is doubtless connected with the fact that these grasses constitute the usual food of the adults.

In most other localities where the larvæ were found the layer of vegetable mold was not as extensive or as clearly defined as in the pasture at Tappahannock. The favorite haunts of the species appear to be low or poorly drained areas where the plant growth approximates that characteristic of the borders of marshes. In such areas the accumulation of vegetable detritus is relatively rapid.

Attempts were made both at Tappahannock and at Charlottesville to rear the larvæ upon cow manure in various stages of decay. Fresh manure appeared to be highly injurious to them, but old, dry, and well-cured manure, when slightly moistened, proved fairly acceptable, although the mortality among the larvæ fed in this way was excessively high. It would seem probable that, while the vegetable constituents of manure may be suitable for the larvæ, other portions

may be toxic for them. This view is supported by results of field observations, which show that larvæ of this species are only very exceptionally associated with manure. Thus in the old pasture at Tappahannock, where the larvæ were abundant, they were never found beneath the droppings of cattle, although repeated search was made for them in such locations. Furthermore, they were no more frequent in fields that had been treated with manure than in those that had been left untreated. The junior writer has repeatedly searched for the larvæ in fields to which manure had been added earlier in the season, but although the larvæ of certain other scarabæids, such as *Ligyrus gibbosus* (De G.), *Dyscinetus trachypygus* (Burm.), and *Cotinis nitida* (L.), were unusually common in such fields, those of *Euethola rugiceps* were either entirely lacking or extremely scarce.

Whether, under natural conditions, the larvæ ever subsist upon living plant material is a question which can not as yet be answered. From the fact that the older larvæ in the breeding experiments were fed with kernels of corn, it would not be unreasonable to suppose that they may feed to some extent upon living plant material. The frequent association of the larvæ with grasses of the genus *Paspalum* suggests the possibility that they may feed upon the rootlets of these plants, though it is also possible that this association is purely accidental—a result of the parent beetles depositing their eggs in such spots while feeding upon the plants.

Howard (7) and Titus (13) have inferred that the larvæ feed upon the dead and dying roots of the kinds of cultivated plants—sugar cane and corn—destroyed by the adult beetles. Titus, indeed, goes so far as to offer the suggestion that the object of the beetles in attacking sugar cane is less to secure food than to provide a supply of dead and decaying vegetation for the larvæ to feed upon. So far as corn is concerned, however, there can be little doubt that the beetles attack it primarily for food, and that if the destruction caused thereby is of benefit to the larvæ it must be a very indirect benefit. The junior writer has tested the capacity of the very young larvæ to feed upon dead and decaying corn rootlets, and, while the experiments were not sufficiently extensive to settle the matter fully, the results were entirely negative.

It has been suggested that the larvæ may feed in decaying wood, as do those of some of the near allies of this species. Examination of old logs and stumps at Tappahannock for larvæ of *Euethola* yielded only negative results, and it seems reasonably certain that they do not occur in such situations.

In the experiments at Charlottesville an effort was made to rear the larvæ from forest leaf-mold, but, although they appeared to eat this, only a very small proportion of the larvæ tested lived beyond the earliest stages. There is no evidence that the larvæ ever feed upon such material under natural conditions. All attempts to find the species in timbered areas were unsuccessful. It is apparently limited to open situations.

GROWTH

The larva on hatching from the egg is approximately 3 millimeters long; when fully grown the length is about 32 millimeters ($1\frac{1}{4}$ inches). Growth is rapid, the larva attaining full size in from

5 to 8 weeks after hatching—usually this is about a week or 10 days before it is ready to enter the prepupa stage.

DURATION OF THE LARVAL PERIOD

The length of the larval period in the experimental series varied from 44 to 94 days. In the majority of cases, however, it falls between 50 and 65 days, a fair average being about 57 days. Instances in which the duration of this stage was greater than this mostly belong to those larvæ which developed late in the season, when low temperatures retarded their growth.

The earliest date at which larvæ have been found at Tappahannock is June 19. This was in 1916, when a few were hatched from eggs collected in the field on June 5. In the breeding experiments of 1915, larvæ were still being hatched as late as November, but this was evidently abnormal, as there is no evidence that any are ever hatched in the field later than the first part of August. The latest date on which the young larvæ have been found in the field is August 12. This was in 1916, when two were obtained in the old pasture at Tappahannock. The latest date on which full-grown larvæ have been observed in the field is November 2. This also was in 1916, when W. T. Emery recorded finding a few larvæ of what he supposed to be this species in the same pasture. These specimens were unfortunately lost before their specific identity could be fully established. As the early fall of 1916 was unseasonably cold, it is not unlikely that such an extension of the larval period as is indicated by Mr. Emery's observation may have occurred.

Although it is possible that the latest developing larvæ may, in some instances, fail to reach maturity before winter, there is no evidence that any ever survive until the following spring. Both field observations and experiments to test this possibility have given only negative evidence. At Charlottesville the larvæ, each in its own box, were buried in a compost heap on the approach of winter, but when the boxes were dug out and examined in the spring all the larvæ were dead.

MOLTING

Experiments to determine the number of molts and the duration of the periods between molts were made at Charlottesville. Each larva upon hatching was transferred to a salve box, the bottom of which was covered with a disk of moist blotting paper on which were placed a few particles of old cow manure, which had been previously fumigated with chloroform. These experiments were begun August 14, 1915, and were continued throughout the fall and early winter. After September 25 the larvæ were kept indoors, where they were subjected to artificial heat. The mortality in these experiments was high, even after vegetable mold had been substituted for the manure. Consequently only a very small proportion of the larvæ completed their development.

Owing to the late date at which these experiments were begun the time intervals recorded between successive molts can have little significance as regards the duration of these intervals under field conditions.

These experiments showed, however, that the larvæ during their growth pass through two molts. There is, of course, a third molt at the close of the prepupa state. This result is in harmony with those obtained by a number of other workers in Coleoptera.

Immediately after hatching, the head shield of the young larva is distinctly wider than the trunk (fig. 3); at this time it is quite soft and pure white. It hardens, however, within a day or two and assumes the normal red color. It then ceases to grow, but the trunk continues to expand and in time exceeds the head in thickness. Then when the larva has attained considerable size it undergoes its first molt. In the process the skin of the trunk splits lengthwise on the dorsal side, while the head shield becomes detached from it and is forced off the head in front. The new head shield is soft and pure white at first; it expands rapidly after the molt and in a short time hardens, assumes the characteristic red color, and again exceeds the body in width. Succeeding molts are accomplished in the same manner.

The larvæ were frequently observed to devour the exuvium shortly after the molt had been completed.

Table 1 gives data on molting experiments at Charlottesville, Va.

TABLE 1.—*Molting records of Eutheola rugiceps, Charlottesville, Va., 1915*

Serial No.	Larva hatched	First molt	Second molt	Third molt	Emergence of adult
Y1.....	} Aug. 14.....	{ Sept. 19	Nov. 4	-----	Jan. 6
Y3.....		{ Sept. 15	Oct. 14	Nov. 21	
Y4.....		{ Sept. 14	Oct. 12	Nov. 30	
Y7.....	} Aug. 27 (?).....	{ Sept. 20	-----	-----	Jan. 18
Y8.....	} Sept. 1 (?).....	{ Sept. 16	-----	-----	
Y9.....		{ Sept. 18	Oct. 18	-----	
Y10.....		{ Sept. 21	Oct. 20	Dec. 10	
Y16.....	} Aug. 14.....	{ Sept. 16	-----	-----	Jan. 18
Y17.....		{ Sept. 21	-----	-----	
Y62.....		{ Oct. 20	-----	-----	
Y63.....	} Sept. 25.....	{ do.....	-----	-----	Mar. 9
Y67.....		{ Oct. 19	-----	-----	
Y71.....		{ Oct. 14	Nov. 13	Jan. 29	
Y72.....	} Sept. 14.....	{ Oct. 11	do.....	-----	
Y73.....		{ Oct. 14	-----	-----	
Y74.....		{ Sept. 27	Nov. 3	-----	
Y75.....	} Sept. 14.....	{ Oct. 18	-----	-----	
Y76.....		{ Oct. 21	-----	-----	
Y79.....		-----	Nov. 19	Jan. 27	

HABITAT

The experience of the writers in Virginia indicates beyond much doubt that the normal habitat of all stages of *Eutheola rugiceps* consists of open grasslands on low or poorly drained areas of relatively heavy, dark-colored soils. The conditions prevailing in the habitat were most fully investigated in the vicinity of Tappahannock, but visits to other points in the State, from which the species has been recorded, show that essentially similar conditions characterize the habitat in all the localities examined.

Similar conditions have also been reported by other writers. Thus Howard (7, p. 12) quotes a correspondent who wrote from Canton, Miss., that this insect was the worst corn pest on heavy, wet land he had ever experienced. Webster (14, p. 159) states that in Tensas

Parish, La., and St. Francis County, Ark., corn on clay soils was damaged by the beetles. Sherman (11, p. 44) records observations of the same character in North Carolina.

In the unpublished records and correspondence of the bureau, additional observations to the same effect are recorded. One correspondent stated that at Dalton, Ga., corn attacked by the beetles was most severely injured in land that had been in meadow and pasture. Another correspondent, of Eutaw, Ala., reported them as doing considerable damage to corn in bottom lands.

Some very interesting observations along the same line have been recorded in his field notes by George G. Ainslie, who investigated an outbreak of the beetles in western Tennessee and Kentucky. In a field at Savannah, Tenn., which he examined, Ainslie observed that the greatest damage to corn was in the lowest part of the field. At Milan, in the same State, he notes that the beetles were most abundant in the lower and moister areas, while at Guthrie, Ky., he found that the greatest injury had been done in a field which adjoined a boggy spot overgrown with large sedges, rushes, and grasses.

While the majority of observers agree in reporting the species as most numerous in heavy, moist soils, Comstock (3, p. 238), on the contrary, states that in the sugar-cane plantations of Louisiana the injury inflicted by the beetles is confined to those sections in which the soil is of a sandy, friable character, and is lacking in those where it is of a heavy, alluvial type.

In the vicinity of Tappahannock, it was found breeding in a number of more or less scattered stations, each of which was examined with regard to location, type of soil, and character of vegetation. These situations were, without exception, confined to the lower, nearly level lands which border the Rappahannock River and which represent a former flood plain.

One of the breeding grounds most thoroughly studied at Tappahannock was the old pasture frequently mentioned in the foregoing pages, and known as "Coghill's pasture." This pasture included about 20 acres, the greater part of which consisted of a rather heavy clay loam of a dark gray or slate color, and was about 2 miles back from the river. It had not been cultivated for at least 25 years and undoubtedly was of a marshy or swampy nature formerly, being considerably lower than surrounding cultivated fields. Many of the lower spots of this pasture had a thick cover of grasses under which was a thin layer of vegetable mold, where, as previously stated, many larvæ of *Euethoea rugiceps* were found.

The vegetation covering this tract was chiefly composed of species of grasses and sedges, the most abundant of which were those belonging to the following genera: *Panicum*, *Paspalum*, and *Fimbristylis*. There were heavy growths of Japan clover (*Lespedeza striata*) in places; in the moistest spots were numerous tussocks of the tall rush (*Juncus effusus*).

A second pasture about 2 miles southeast of Tappahannock resembled Coghill's pasture in all essential respects. It joined a woodland locally known as White Oak Swamp, and was really reclaimed swamp, so the junior writer was informed. Larvæ were plentiful here, also, under the heavy growths of *Paspalum laeve*.

A third breeding ground was in a pasture close to the Rappahannock River, bordering a tidal marsh. This pasture was quite low,

its highest point probably not exceeding 4 feet above tide, from which point it sloped gently toward the marsh. Most of the larvæ of *Euetheola rugiceps* were found within a few yards of the marsh under growths of *Paspalum laeve*, the soil at that point being moist but not soggy. The soil and vegetation here were essentially similar to those in the Coghill pasture.

Larvæ of *Euetheola rugiceps* were found in a number of other locations near Tappahannock and wherever found in numbers the locations were similar in all essential respects to the pastures previously described.

Besides occurring in what may be considered their normal habitat, larvæ have been found in locations that are not entirely typical. Such occurrences seem very localized and are restricted to areas near the normal breeding grounds. Also, larvæ seem rarely to reach maturity in well-cultivated fields. For example, in cornfields near old breeding grounds, and in which the corn was practically destroyed, very few full-grown larvæ could be found.

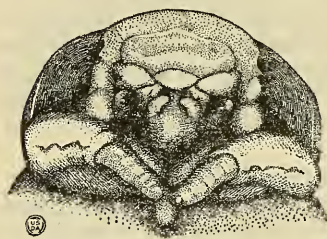


FIG. 4.—Ventral view of head region of pupa of *Euetheola rugiceps*, showing structure of mouth parts. (Drawn by Henry Fox from photograph by J. H. Paine)

able injury from *E. rugiceps*, the greater part of the injury being in the vicinity of the spot where the larvæ were so plentiful the preceding year. This does not prove conclusively, however, that a good part of the injury was not due to migrating beetles from the old pasture.

The soil in the timothy sod of the field just mentioned was a fine, rather sandy loam. Fine sandy loams appear to constitute the dominant types throughout most of the region bordering the Rappahannock River. These soils apparently harbor *Euetheola rugiceps* only in the poorly drained areas that have become overgrown with wild grasses. In the opinion of the writers thorough cultivation combined with good drainage will eliminate *E. rugiceps* as a corn pest in such localities.

PREPUPA

In the beginning of the prepupa stage the larva ceases to feed and becomes relatively quiescent, the power of movement being retained only within the posterior half, which is capable of being bent forward beneath the thorax and then straightened out again. This movement may be repeated a number of times in rapid succession and is doubtless of use in assisting the creature to enlarge the cavity or cell in which the pupa stage is passed, as well as in splitting the larval integument and thereby freeing the inclosed pupa. During the pre-

pupa stage the larva lies on its back, in a slightly curved position, in the cavity formed by its movement in the soil. While still inclosed in the old integument, the larva undergoes its transformation into a pupa. This process is initiated by the withdrawal of the internal mass of the body from the larval integument at its hind end, which becomes greatly shriveled. Finally, when the pupal body has been formed, the larval skin splits along the dorsal line, revealing the fully formed pupa within. The latter frequently passes its entire existence inclosed within the split larval skin.

PUPA

DESCRIPTION

The pupa of *Euethola rugiceps* measures on the average about 15 millimeters in length, and is pale buff. Its general form is shown in Plate IV, A, and certain of its structural features in Figures 4, 5, and 6, but probably its most distinctive peculiarities are those of the mouth parts (fig. 4). The mandibles are relatively stout, roughly triangular in outline, and with the apex forming a rounded angle. The labrum is quite wide transversely, and has its free edges regularly and evenly arcuate. The maxillary palpi

Fig. 5.—Ventral view of posterior end of abdomen of male pupa of *Euethola rugiceps*, showing sexual characters. (Drawn by Henry Fox)

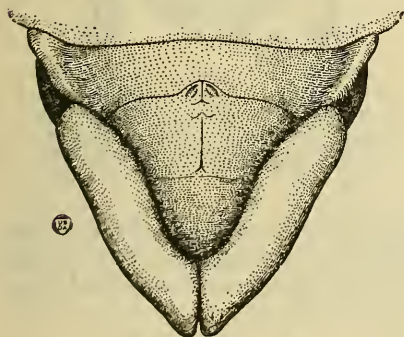
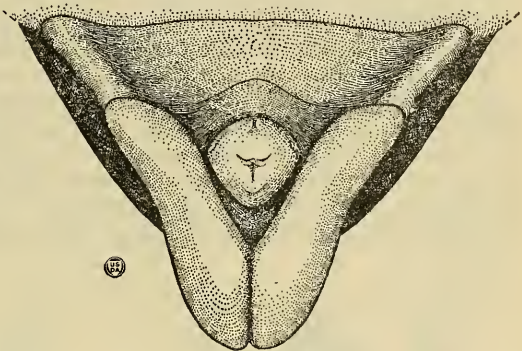


Fig. 6.—Ventral view of posterior end of abdomen of female pupa of *Euethola rugiceps*, showing sexual characters. (Drawn by Henry Fox)

are short, conical structures which are nearly vertical in position and have their tips projecting but slightly below the level occupied by the other mouth parts.

Other distinctive characters are afforded by the shape of the post-coxal process of the prosternum, which is rather short, blunt, and constricted near the middle, and by the elytral pads, which are smooth, or, at most, only obscurely costate.

Sexual characters in the pupa occur in the ventral surface of the last abdominal segment. In the male this bears a prominent hemi-

spheric protuberance, the apex of which is slightly indented (fig. 5); in the female this structure is lacking, but instead there is a minute median projection of the anterior border of this segment into the segment in front (fig. 6). This process shows a pair of lateral, more fully chitinized areas which probably correspond to the genital plate of the adult female.

DURATION OF THE PUPA STAGE

The pupa stage may last from 9 to 44 days, but usually falls between 10 and 19 days, so that two weeks may be said to be a fair average period for the duration of the stage under normal conditions. The precise length of this period unquestionably is determined by the prevailing temperatures. Instances in which the length of the stage is much in excess of the normal pertain to individuals which have undergone their development late in the season.

The earliest date on which pupæ have been obtained at Tappahannock is July 31, when there appeared in one of the breeding boxes a pupa which had developed from a larva collected at the same locality on June 30. The earliest record of actually finding pupæ in the field is August 12. They appear to be most abundant during the last part of August and first half of September. Pupæ have been found in the field as late as November and it seems quite probable that a small

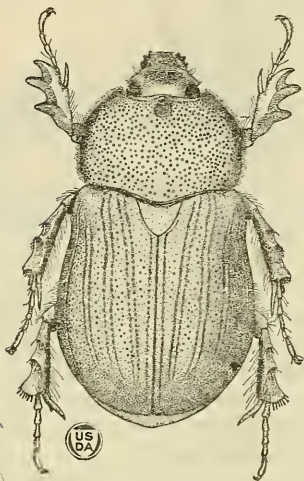


FIG. 7.—*Eutheola rugiceps*: Adult. (Drawn by Henry Fox)



FIG. 8.—Ventral view of adult *Eutheola rugiceps*, showing structural characters. (Drawn by Henry Fox)

number may fail to mature before winter. There is no evidence that such pupæ ever survive until the following spring, as all the pupæ in the possession of the writers buried in the ground at Charlottesville perished during the winter.

ADULT

DESCRIPTION

The adult of *Eutheola rugiceps* (Pl. I, B; II, A; figs. 7, 8) is a rather stout, jet black beetle, having an average length in Virginia and Tennessee material of from 13 to 16 millimeters. The surface in recently emerged individuals is highly polished,⁵ but is dull and opaque in old and worn ones.

⁵ Casey (1, p. 187) in his recent memoirs asserts that the body is "not very shining," and gives this as one of the characters distinguishing *Eutheola rugiceps* from another form from Honduras, which he describes as a new species, *hondurana*. The writers are inclined to think from Casey's description that he had at hand only old individuals of *rugiceps*—doubtless collected during the spring, as the younger ones, collected in the fall, are almost invariably rather highly polished and of an intense black color.

CORRECTION SLIP

Department Bulletin 1267, The Rough-Headed Corn Stalk-Beetle.

The cuts of Figure 7, page 18, and Figure 14, page 26 should
be transposed, as the former is that of Ligyris gibbosus
and the latter is that of Euetheola rugiceps.

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The head is rather short, its median length being about half its maximum width. Its surface is marked by numerous transverse, undulate rugulae (fig. 8) which are reduced to minute granulations on the front half of the clypeus and disappear on the occiput, which is quite smooth, except for a few sparse, shallow punctures. The clypeus has strongly oblique sides which are conspicuously margined and elevated. Immediately in front of the clypeal suture the head is crossed by a rather low, transverse ridge, or carina, which is broadly interrupted in the middle. The apical margin of the clypeus is almost truncate and rather short, being only about one-fourth the width of the base. It is dorsally reflexed and crested, the crest being interrupted in the middle by an oblique sinus, which separates the two conical processes—the so-called “teeth”—arising from the crest. These “teeth” in fresh specimens are rather high and sharp, but in old and worn specimens are frequently reduced to mere stumps. The mandibles are visible from above beyond the sides of the clypeus, and are very unequally bidentate, the anterior tooth, which is upturned at the apex, being much larger than the short, obtuse, posterior one.

The pronotum is distinctly wider than long, and about twice as wide as the head. Its sides are broadly and evenly arcuate and narrowed slightly anteriorly, the surface being smoothly and uniformly convex, bearing numerous coarse, annular punctures which are somewhat sparsely distributed throughout but rather more crowded on the sides than in the middle. The anterior and lateral borders are clearly margined, the posterior plain and feebly bisinuate. The antero-lateral angles are sharply produced anteriorly, while the postero-lateral ones are broadly rounded and obtuse-angulate.

The scutellum, although rather small, is quite distinct, the surface being smooth, except for a few minute punctures.

The elytra are but slightly longer than their combined width, which is not obviously greater than that of the pronotum. Each is longitudinally traversed by a number of slightly impressed, double rows of rather coarse, circular punctures, these giving the elytra a somewhat striate appearance (fig. 7). Anteriorly these punctures are frequently confluent and variolate. Outside of the double rows of punctures, the entire surface of the elytra is covered with numerous closely set and irregularly distributed punctures, which, for the most part, are essentially similar to those forming the double rows, but are reduced on the sides and apical half to minute, punctate impressions.

The stridulating organs on the inner surface of the elytra are very feebly developed.

The labium (fig. 8) is considerably longer than wide, and is appreciably narrowed at its apical end, which is feebly bilobed and marked by sharply elevated lateral margins situated under the insertion of the palpi; the basal half is rather strongly convex, without lateral margins, and bears on the sides numerous long stiff bristles, which are largely lacking toward the center.

The prosternum (fig. 8) bears a stout, erect, cylindrical, postcoxal process or spine, the apex of which is almost flat and occupied by a smooth, padlike surface, the hind margin of which bears a conspicuous, radiating fringe of long, stiff bristles.

The surface of the mesosternum and metasternum is nearly smooth, or at most but very sparsely and indistinctly pilose. The metasternum bears numerous shallow, circular punctures, larger and coarser on the side than in the middle, each of which is frequently provided with a minute, barely visible bristle or seta. The mesepisternum has its surface somewhat rugulose and bears a rather sparse covering of stiff hairs.

The forelegs are relatively stout and are adapted for digging. The tibiae bear on the hind margin four distinct, toothlike projections, three being long, stout, and acute; the fourth, or uppermost, much smaller and decidedly obtuse.

SEXUAL CHARACTERS

The last ventral segment of the male (fig. 9) bears near the anal margin a transverse fringe of short, stiff hairs which is broadly interrupted in the middle; back of this interruption or hairless interval there is a short postanal fringe. In the female (fig. 10) the same character is also present, but there is no median break, the fringe being continuous.

A less obvious difference between the sexes is, as pointed out by Casey, in the form of the pygidium, which is slightly shorter, more convex, and more broadly rounded at the apex in the male than in the female.

The male claspers (fig. 11) are symmetrical, each consisting of a vertical flange resembling that of *Ligyryus gibbosus* (fig. 12) but considerably smaller and slenderer and with the upturned process on its postero-lateral face more nearly basal, toothlike, and extending obliquely backward. The female genitalia consist of two pairs of almost flat plates—a large superior and a small inferior pair, the latter fringed apically with short hairs. A pubic process is lacking.

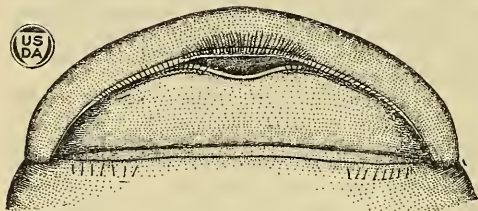


FIG. 9.—Ventral view of tip of abdomen of adult male *Euethiola rugiceps*, showing structural characters. (Drawn by Henry Fox)

TIME OF EMERGENCE

The earliest date on which adults of the newly emerged generation have been observed under laboratory conditions at Tappahannock is August 13. This was in 1915, when an adult, reared from a larva collected June 30, appeared in one of the breeding boxes. The earliest date on which adults have been found in the field is August 24 (in 1915 and 1916).

The period of emergence extends throughout the last part of August and the whole of September and October, although ordinarily relatively few appear to emerge later than the end of September. The latest emergence of which there is record is of two individuals which developed in the breeding boxes early in November. In 1915 the majority of the beetles emerged between September 1 and September 25, the period between September 10 and September 20 being especially prolific in emergences.

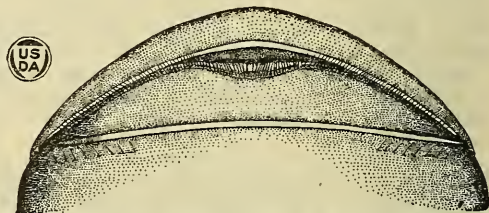


FIG. 10.—Ventral view of tip of abdomen of adult female *Euethiola rugiceps*, showing structural characters. (Drawn by Henry Fox)

COLOR CHANGES

When the adults emerge from the pupa they differ greatly in color from the typical mature beetles. The earliest changes in color take place during the closing days of pupal existence, while the adult is still inclosed within the pupal integument. These changes involve only the head and thorax, which at the time of emergence are already well chitinated and bright orange red. The elytra, however, at this time are quite soft and colorless, but assume a pale creamy hue within an hour or two, also becoming perceptibly firmer; in a few hours more this changes to a bright orange. The following day, under normal conditions, the color of the elytra gradually grows darker, becoming a vermilion red or Indian red. In the meantime the head and thorax have been changing color

rapidly and have become considerably darker than the elytra and are a deep purplish red. The elytra soon acquire the same shade. The final stage naturally is the transformation of this color into the deep black of the typical beetle.

Under favorable conditions these color changes are completed in from four to five days, but in cooler weather the time required to effect them may be greatly extended. Thus, in October and November, beetles were frequently found to retain their red coloration for a period of two or three weeks.

ACTIVITY IN THE FALL

The adults appear to be much less active in the fall than in the spring. So far as the writers are aware, there are no records of the beetles having been taken at lights during this season. At Tappahannock, in the fall of 1915, they were frequently observed on or immediately under the surface in the places where they had emerged. Almost invariably they were to be found beneath clumps of their favorite food plants, *Paspalum* spp., boring into and cutting off the culms of these grasses. The junior writer never observed any of the beetles outside of their natural habitat at this time of the year, but W. T. Emery, who visited the breeding grounds of the species at Tappahannock in early November of 1916, reported that he had seen a small number crawling on an adjoining highway. Mr. Emery states that the day on which these beetles were observed was unusually warm and mild, a circumstance which doubtless accounts for their wandering abroad.

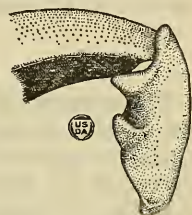


FIG. 11.—Lateral view of male clasper of *Euctheola rugiceps*. (Drawn by Henry Fox)



FIG. 12.—Lateral view of male clasper of *Ligyrus gibbosus*. (Drawn by Henry Fox)

HIBERNATION

No systematic observations on the hibernation of the beetles were made. So far as the available evidence goes, it indicates that hibernation takes place in the normal feeding ground of the species and in much the same manner as in other scarabaeids which pass the winter in the adult stage. On one occasion during the plowing of a timothy pasture at Tappahannock in February of 1916, the junior writer picked up a few beetles of this species. The depth at which they occurred could not have exceeded 8 inches and was probably less. From the fact that some larvæ reach maturity in cultivated fields, it is probable that many hibernate there, but they are insignificant in comparison with the much greater numbers that hibernate and emerge in the normal habitat of the species.

Experience with beetles kept in cages outdoors, during the winter of 1915-16, indicates a heavy mortality among the hibernating beetles during this season in the latitude of Virginia. At both Charlottesville and Tappahannock only about a third of all the

beetles placed in the hibernating cages in the fall were living when the cages were examined in the spring. That an equally heavy mortality may obtain under natural conditions is indicated by the fact that where the beetles had been quite abundant in the fall of 1915, only a few could be found in the following spring. Doubtless if the species could be kept under constant observation for a succession of years, it would be found that winter conditions constitute one of the important factors controlling the destructive outbreaks of the species which seem to occur at rather long intervals.

APPEARANCE IN SPRING

The beetles usually begin to emerge from their hibernating quarters in the spring in late April or in early May, except in the most southern portions of its range. The precise time of emergence is governed by prevailing weather conditions. Comstock (3) states that they become active as early as the middle of March in Louisiana. At Tappahannock the earliest dates on which they have been seen abroad were April 23 in 1915 and May 1 in 1916. At Clarksville, Tenn., the junior writer first observed them at street lamps on April 18, 1917. McConnell recorded them (unpublished notes) as active and destructive at Greenwood, Miss., on April 23, 1913. Webster (14) reported them damaging corn in Louisiana on April 25, 1888. Becker informed the junior writer that complaints of injury by the beetles came in from southern Arkansas about May 1.

MATING

Mating of *Euethoea rugiceps* is practically coextensive with the period of its maximum activity. The earliest date on which the beetles were observed *in coitu* was May 13, 1915, at Sharps, Va., while the latest date on which they were observed mating under natural conditions was June 20, 1915, at Tappahannock. In the case of those kept in breeding cages, mating was observed much later than this, one pair being observed *in coitu* as late as September 10. Mating normally takes place underground, though on one occasion a pair were found *in coitu* on the surface in a slight hollow at the base of a cornstalk; they were also found mating in tin boxes in which they were placed during collection. It seemed to be immaterial to the beetles whether soil was in the boxes or not.

OVIPOSITION

Oviposition was observed to occur at Tappahannock chiefly during June, the earliest eggs being found on June 5. It would seem probable that eggs may be deposited during July, but the writers have no records of obtaining any during that month. Most of the eggs are apparently deposited during the last half of June. Beetles kept in cages under somewhat artificial conditions continued oviposition, except for temporary interruptions due to the inclement weather, throughout the summer, and until as late as the last of September; a small number of eggs even being deposited in October and in early November. In nature, however, such prolongation of the breeding season evidently does not occur, as field experience indicates beyond a reasonable doubt that practically all the beetles

of the egg-laying generation of the year have perished by the first of August.

At Tappahannock, eggs, or recently hatched larvæ, were found in hills of corn and in a layer of vegetable mold. In this vegetable mold they were often deposited at the base of tussocks of the common rush, beneath clumps of pasture grasses, especially those of the genus *Paspalum*, and under low mats of Japan clover. The eggs hatch within two or three weeks under normal summer conditions.

ACTIVITY IN THE SPRING

The beetles are unquestionably much more active and attract far more attention in the spring than during the fall. This is due doubtless to the activities connected with feeding and reproduction. The beetles are rather sluggish, and if their needs are adequately met they apparently do not roam much. When, from any cause, their needs are not satisfied, they may come out of the ground and go elsewhere in search of more favorable locations, either by flight or by crawling away on the surface. Apparently the beetles fly only at night, when they are frequently attracted to lights, but the junior writer has repeatedly observed them crawling on the surface in bright daylight.

From observations made on caged individuals, it would appear that the impulse to wander may come from lack of food as well as from the instinct to mate. Thus, in cages in which beetles were confined without food, they often came out on the surface, especially at night, and crawled up the sides of the cages, frequently attempting to take flight; whereas in adjoining cages, in which the inmates were plentifully supplied with food, it was a rare event for one to be found on the surface at any time. A beetle has occasionally been observed to emerge from a hill of corn in which all the plants had been killed and move off to another where the plants were intact.

FOOD PLANTS AND CHARACTER OF INJURY BY THE BEETLE

Eutheola rugiceps is best known as an enemy of corn and sugar cane, but there is reason to believe that these are not its normal food plants. During the fall of 1915 the junior writer found them feeding abundantly upon certain species of grasses belonging to the genus *Paspalum*. These grasses have since been found in every section visited by him in which the species has been found or from which it has been reported, and there is accordingly every reason to believe that they constitute the favorite food of the beetles. Beetles kept in confinement ate the plants eagerly. At Tappahannock the species of *Paspalum* fed upon were determined as *P. laeve* and *P. plenipilum*. The large, coarse-stemmed forms, such as *P. floridanum*, do not appear to be acceptable to them. The beetles attack these grasses in much the same manner as they do corn, forcing their way beneath the tufts, or coming up under them from below, and boring into the culms where the latter lie in contact with the ground. Sometimes the culms are cut completely off, but even when they are not entirely severed such a thin and broken bit of tissue is left connecting the parts that the portion beyond the injury quickly wilts and dies. In the fall of 1915 it was a common occurrence to find large patches of *Paspalum* which had been almost or quite completely destroyed by them.

The beetles also feed upon the common rush (*Juncus effusus*). The culms of this plant form a dense tuft and are extremely tough and dry, except at the base, where they are somewhat tender. The beetles attack and cut them off at that point. Owing to the crowded condition of the culms at the base of the plant, it was not possible to detect the beetles at work, but they were found lying motionless in such situations and beside the broken and shredded culms. Tufts of the rush, from which all imperfect culms had been carefully removed, were transplanted to a cage containing the beetles and, when examined several days later, were found to have a considerable number of their culms broken off and shredded in the same manner as those observed in the field. It would appear, however, that the beetles prefer the *Paspalum* grasses to the rush.

Bermuda grass (*Capriola dactylon*) also is probably eaten by the beetles, though very much less readily than *Paspalum*. This grass occurs practically everywhere throughout the entire coastal section of Virginia and is especially characteristic of the better cultivated areas. It abounds in many situations in which *Paspalum* is scarce or lacking. Indeed, it would seem that the chief danger of *Euetheola rugiceps* perpetuating itself in farming districts and other places outside its typical habitat lies in the universal presence of this grass and the apparent ability of the pest to utilize it as food when no other is available. One would imagine that the hard and wiry stolons of Bermuda grass would scarcely prove very attractive; nevertheless the junior writer has repeatedly found them torn and frayed in the manner characteristic of injury by this species. Similar injury has also been caused by planting the stolons in a cage containing the beetles.

Corn is attacked by the beetles only in the spring and early summer when it is young. Later in the season the stalks become too hard for them to penetrate. The plants may be attacked as soon as they appear above ground, and are not safe from serious injury until they are fully waist high. The beetles are particularly fond of the apical growing point of the stalk, the so-called "heart," which is the most vital and important part of the plant. In the early stages of growth of the corn plant this structure forms a minute conical bud, situated below the surface of the ground in the center of the stalk. To reach this part the beetle bores into the stalk at any point between the surface of the ground and the point of attachment of the roots, making a large, ragged opening (Pl. I, B). The work of the beetle is indicated above ground by wilting of the inner set of leaves, the outer ones retaining their rigidity for a considerable period after the other leaves have died.

In a somewhat later stage of growth, after the stalk proper has begun to elongate and has carried the terminal bud well above ground level, the injury done by the beetle boring into the stalk is usually less severe, only a more or less extensive part of the pith at this time being destroyed, the more vital growing part being out of reach of the beetles. At this time the stalk is also considerably thicker than before, and a beetle may finish feeding before it has destroyed enough of the vascular supply of the plant to interfere seriously with its functions.

The chief danger to larger corn plants is naturally in the weakening of the stalk, which may result in its being blown over or broken

off by strong winds. Plate I, A, represents a badly injured cornfield in the vicinity of Tappahannock. This field had been replanted several times. There were a number of fields showing such injury in the vicinity of Tappahannock.

An interesting discovery in relation to the feeding habits of *Euetheola rugiceps* is that it will feed readily on apples, either in breeding cages or in the field. This fact was first ascertained by Ezra Shackelford, at Tappahannock, who informed the junior writer that he had found a beetle feeding on a fallen apple in the orchard. This observation subsequently was verified.

All efforts to find the beetles feeding under natural conditions on common grasses other than *Paspalum* spp., and Bermuda grass were futile, though in breeding cages they were induced to accept *Panicum lindheimeri* and *Fimbristylis baldwiniana*. The indications, however, are that the beetles do not like these plants, and that they feed upon them only when deprived of all other food.

Since ironweed (*Vernonia noveboracensis*) was a common weed in the typical habitat of the species, an experiment was made to ascertain if the beetles were capable of utilizing it for food. The results were entirely negative. The junior writer found that the common ragweed (*Ambrosia artemisiifolia*), the well-known food plant of *Ligyris gibbosus*, was unacceptable to *E. rugiceps* in breeding cages, nor could they ever be found attacking these plants in the field.

One or two correspondents of the Bureau of Entomology have stated that potatoes are occasionally injured by *Euetheola rugiceps*. To test this point, the junior writer on one occasion buried a few tubers in a cage containing a considerable number of beetles, but the latter apparently took no notice of them.

At Tappahannock *Euetheola rugiceps* could never be found attacking the common grass locally known as goose-grass (*Eleusine indica*), but to ascertain if the beetles are capable of subsisting on it a quantity was transplanted to one of the cages containing the beetles. When examined a week later it was found that a number of the culms had been shredded to some extent at the base, but that in only a few was the injury serious. Evidently the beetles do not willingly feed upon this grass, but may possibly do so to a slight extent if unable to obtain more acceptable food.

Since the beetles were found to be rather common in one of the timothy-clover pastures at Tappahannock, tests were made to ascertain if the beetles would feed upon these plants. In both instances they were untouched. It is probable, therefore, that beetles living in timothy and clover fields derive their sustenance from some other plant associated with them. This, in all likelihood, is Bermuda grass, which is usually common in such fields.

Occasionally the adults are accused of damaging rice. The writers have never had an opportunity to study the species in rice-growing sections and are unable to speak on this matter from personal observation. Inasmuch as *Euetheola rugiceps* in one or two instances was reported as injuring rice, and subsequently proved to be the allied species *Dyscinetus trachypygus*, the writers can not avoid the suspicion that all other reports of such injury may be cases of mistakes in identification. Superficially the adults of the two species are much alike and may be easily confused by persons not familiar with their distinctive characters.

DURATION OF THE ADULT STAGE

The writers have stated that the adults of the overwintering generation of *Euethola rugiceps* perish, under natural conditions, by midsummer. In the experimental cages numerous beetles of this generation not only survived the summer but in some instances lived until late in the fall. This late survival possibly was due to the protection which the beetles received from the extremes of heat and dryness to which in nature they are exposed. A heavy mortality among the beetles immediately after the mating season is evidenced not only by the large numbers of dead beetles found in the field at that time but also by the fact that corn planted late in the season—after June 1—is almost invariably much less severely damaged than that planted earlier. The longevity of adults in the breeding cages was undoubtedly due to the better care they received, as other adults, confined in similar cages but left exposed in the open to as nearly natural conditions as possible, perished in midsummer within a few weeks after the cages were started.

This view is supported by the testimony of others who have had experience with this species. Howard (7) mentions a correspondent at Canton, Miss., who reported that previous to July 9 he had had little difficulty in finding the adults, but after a week of dry weather they had entirely disappeared. Sherman (11) also quotes a correspondent who, writing on June 14, reported that, although the beetles had been very numerous and destructive in his cornfields, he had noticed that within the last few days the dead beetles could be seen all about the field. He added that his corn crop had been so completely destroyed that the field was plowed up on June 1 and a new crop planted a week later but that this second crop remained uninjured.

Apparently the duration of the adult stage in the latitude of Virginia is from 9 to 11 months. The results obtained in experiments indicate that under exceptional conditions in nature the adult stage may conceivably last from a year to 14 months.

SPECIES LIKELY TO BE MISTAKEN FOR EUETHEOLA RUGICEPS

Euethola rugiceps is often associated with other species of scarabaeid beetles which may be easily confused with it. Its most constant associates are its close allies, *Ligyris gibbosus* (De Geer) and *Dyscinetus trachypygus* (Burm.). For this reason these two species will be considered in somewhat greater detail than the remaining forms.

LIGYRUS GIBBOSUS (De Geer)

The life history of *Ligyris gibbosus* is essentially the same as that of *Euethola rugiceps*. The larvæ of *L. gibbosus* develop more rapidly, consequently the adults of the new generation appear earlier in the fall than those of *Euethola rugiceps*. The writers have never found *L. gibbosus* injuring corn in the field, nor could it be induced to feed upon corn in breeding cages.

LARVA

In general form, size, and coloration the larva of *L. gibbosus* resembles that of *E. rugiceps*. As in the latter the fully chitinized

head is of a distinctly reddish color but, unlike *E. rugiceps*, the head is smooth or at most but slightly rugulose, lacking almost entirely the deep punctures which are so conspicuous in the latter species. (Pl. III, *A* and *B*.) Furthermore, in the larva of *L. gibbosus* there is no trace of a median double row of modified bristles on the last ventral segment, such as occurs in *E. rugiceps*. (Pl. III, *D* and *E*.)

PUPA

The pupa of *L. gibbosus* (Pl. IV, *B*) is distinguished from that of *E. rugiceps* by certain characters associated with the mouth parts, by the form and position of the postcoxal process of the prosternum, and by the prominent bicostate elytral pads (Pl. IV, *A* and *B*, and figs. 4 and 13). The mandibles (fig. 13) are much smaller and slenderer than those of *E. rugiceps*, and are further characterized by the truncate, not angulate, apex which lies in contact with the nearly straight sides of the labrum. The maxillary palpi are also shorter and rather more rounded at the apex than in *E. rugiceps*. The postcoxal process of the prosternum is less nearly erect and the apex is rather more acuminate than in *E. rugiceps*.

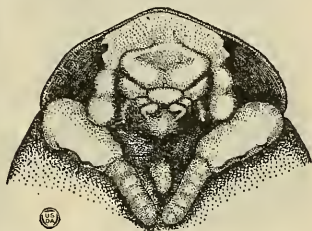


FIG. 13.—Ventral view of head region of pupa of *Ligyrrus gibbosus*, showing structure of mouth parts. (Drawn by Henry Fox from a photograph by J. H. Paine)

ADULT



FIG. 14.—*Ligyrrus gibbosus*: Adult. (Drawn by Henry Fox)

In general form and size the adult of *L. gibbosus* (fig. 14) resembles that of *E. rugiceps*, but is usually distinguishable at a glance by its reddish brown color and by the distinctly hirsute character of its ventral surface. Occasionally adults are found in which the color is so dark as to be almost black. The most reliable differential character is the presence in *L. gibbosus* of a median pit or depression close to the anterior margin of the pronotum, which is entirely lacking in *E. rugiceps*. In front of this pit is a blunt spine or tubercle. Other distinguishing characters of *L. gibbosus* are the absence of transverse rugulae and the presence of a continuous transverse ridge on the dorsal surface of the head.

The stridulating areas on the inner surface of the elytra are well developed in *L. gibbosus* and are capable of producing a low but audible sound, which is usually heard whenever the beetles are handled. In *E. rugiceps* the stridulating area is barely recognizable and is apparently functionless.

DYSCINETUS TRACHYPYGUS (Burm.)

The life history of *Dyscinetus trachypygus* agrees very closely with that of *Euethola rugiceps*. Development takes place at about the same rate in both species. Both may occur in similar situations, though *D. trachypygus* appears to be more tolerant of the products of organic putrefaction. Thus it has been taken in both adult and larval stages in compost heaps and in the vicinity of pigpens, situations in which *E. rugiceps* has thus far never been found. There is no evidence that the adults of this species ever injure corn, as all experiments made to test this possibility yielded only negative results. Farther south they attack rice, and for that reason the species has been given the popular name of "rice beetle."

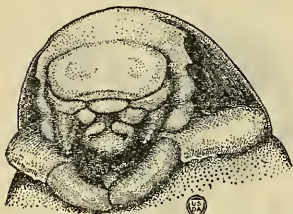


FIG. 15.—Ventral view of head region of pupa of *Dyscinetus trachypygus*. (Drawn by Henry Fox)

LARVA

The larva differs from that of *E. rugiceps* mainly in the entire absence of anything suggestive of a median double row of modified bristles on the last ventral segment (Pl. III, *F*). The surface of the front of the head is sculptured as in *E. rugiceps* (Pl. III, *A* and *C*).

PUPA

The pupa of *D. trachypygus* (Pl. IV, *C*) is readily distinguished from that of *E. rugiceps* by its longer and smoother head and by the form of the mouth parts. The mandibles are much longer and more slender than in either *E. rugiceps* or *L. gibbosus*, and terminate in a short, nearly truncate apex which lies in contact with the sides of the relatively small labrum (fig. 15). The maxillary palpi are unusually elongate, with an acute apex, and project considerably beyond the general level of the other mouth parts. The postcoxal process of the prosternum is more nearly oblique and rather more blunt than in *E. rugiceps*.

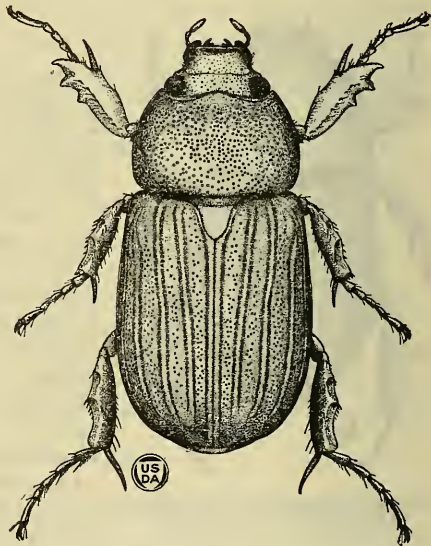
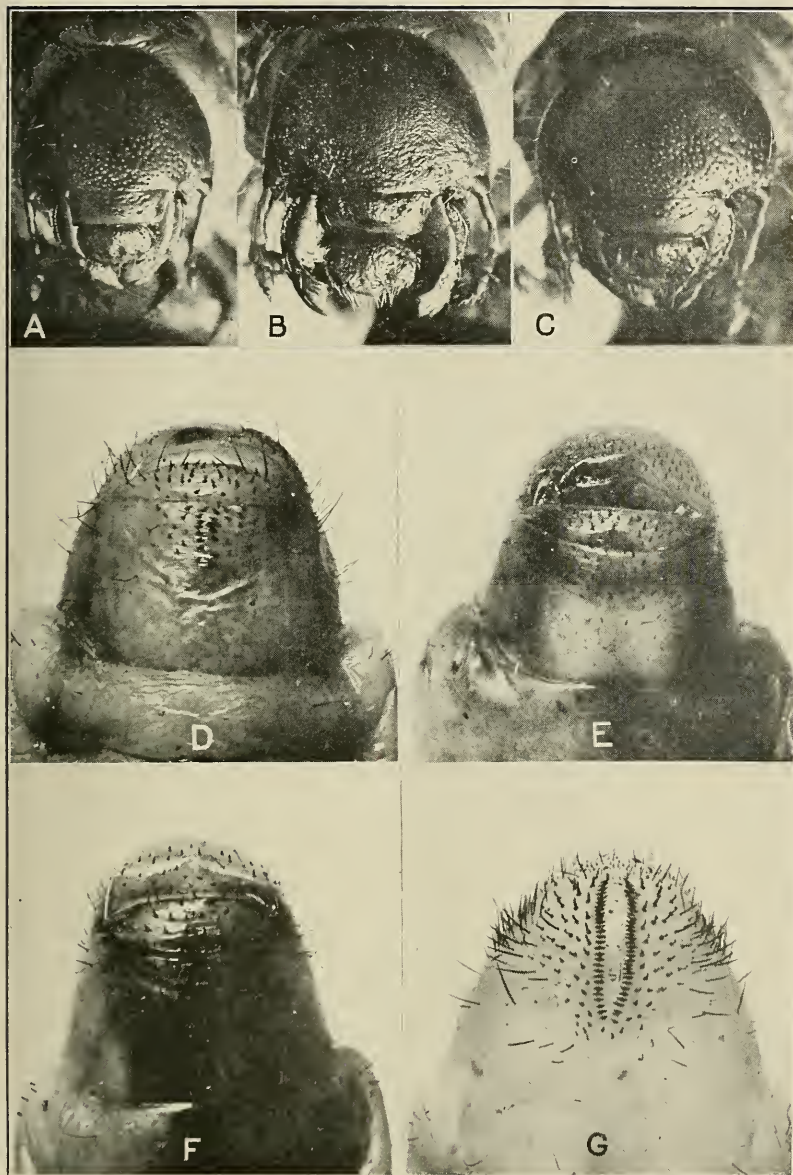


FIG. 16.—*Dyscinetus trachypygus*: Adult. (Drawn by Henry Fox)

ADULT

D. trachypygus (fig. 16) may be readily recognized by its toothless mandibles and by the form and smoothness of the head. The latter is both longer and wider than in either *Euethola* or *Ligyris*

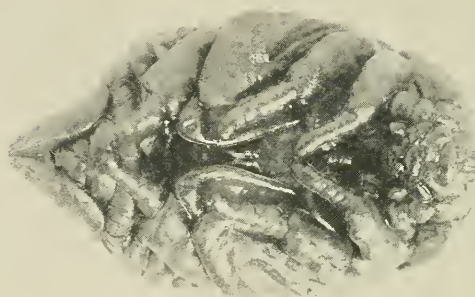


THE ROUGH-HEADED CORN STALK-BEETLE AND SPECIES LIKELY TO BE MISTAKEN FOR IT

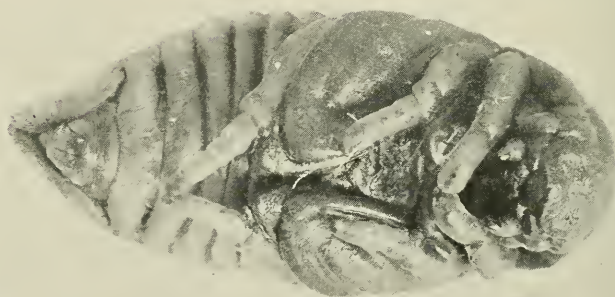
A, Frontal view of head of larva of *Euthcola rugiceps*, showing the strongly punctate surface; B, frontal view of head of larva of *Ligyrus gibbosus*, showing its relatively smooth surface; C, frontal view of head of larva of *Dyscinetus trackypygus*, showing its strongly punctate surface; D, ventral view of anal region of larva of *E. rugiceps*, showing median double row of modified bristles on last segment; E, ventral view of anal region of larva of *D. gibbosus* (note absence of any trace of a median double row of modified bristles on last segment); F, ventral view of anal region of larva of *D. trackypygus* (note entire absence of a median double row of modified bristles and relative coarseness of bristles); G, ventral view of anal region of larva of *Phyllophaga* sp., showing sharply differentiated median double row of modified bristles on last ventral segment. (Photographs by J. H. Paine)



A



B



C



THE ROUGH-HEADED CORN STALK-BEETLE AND SPECIES LIKELY TO BE
MISTAKEN FOR IT

A, Pupa of *Eutheola rugiceps*; B, pupa of *Ligyrus gibbosus*; C, pupa of *Dyscinetus trachypygus*. (Photographs by J. H. Paine)

and is characterized by its large, nearly rectangular clypeus which is separated from the epicranium by a distinct clypeal suture. The surface of the head is smooth except for a number of rather sparse punctures and is entirely devoid of either rugulæ or a transverse ridge.

CYCLOCEPHALA spp.

The only stages in the life history of *Cyclocephala* likely to be confused with *Euethiola rugiceps* are the larva and the pupa. The larvæ of *Cyclocephala* are somewhat smaller than those of *E. rugiceps* and of more yellowish hue. They also differ in the smooth and shiny surface and yellowish amber color of the head shield and in the entire absence of any trace of a median double row of modified bristles on the last ventral segment. The distinctive character of the pupa was not fully studied in this investigation, but the possibility of confusing it with the same stage of *Euethiola* is largely eliminated by the fact that the two occur at entirely different periods of the year. Thus, at Tappahannock, pupæ of *Cyclocephala* were obtained from the last of May to the early part of July, whereas those of *E. rugiceps* were never taken before August.

PHYLLOPHAGA spp.

So far as adults of *Phyllophaga* are concerned there need be no difficulty in distinguishing them from *Euethiola rugiceps*, while the larvæ may be recognized by the reduced size and triangular outline of the supraanal plate, the angular form of the anal slit, the smooth and shiny surface and yellowish color of the head shield, and the presence of a conspicuous, sharply defined, double row of modified bristles on the last ventral segment (Pl. III, G).

NATURAL ENEMIES

The data on the predacious enemies of *Euethiola rugiceps* are very incomplete, and little of importance has been added in the course of this investigation. The underground habits of the species render it difficult to obtain direct evidence of predatory enemies, and only a very small proportion of the individuals collected were parasitized.

At Tappahannock the fields infested with *E. rugiceps* were observed to be frequented by flocks of crows, grackles, and bobolinks, which were probably feeding upon the beetles, though direct proof of this was not obtainable. The Bureau of Biological Survey, however, has found specimens of *E. rugiceps* in the stomachs of the crow, meadowlark, and bluebird, and of species of the closely related genus *Ligyris* in the stomachs of numerous birds.

Among the possible insect foes of *E. rugiceps* may be mentioned several species of Carabidae (ground-beetles), Asilidae (robber-flies), and ants. Carabid beetles were normally common in underground situations and were of frequent occurrence in the places where *E. rugiceps* has been found, but the writers have no direct evidence that they attack or kill the latter, though it seems likely that the smaller larvæ, at least, may at times be the victims of these predacious beetles. As for the Asilidae, Titus (13) mentions the larva

of a robber-fly (*Erax lateralis* Macq.) as an enemy to this and other scarabaeids. At Tappahannock the junior writer observed the larvæ of a similar or closely related form preying upon larvæ and pupæ of a species of *Phyllophaga*, but never found it attacking those of *E. rugiceps*. Ants were found to attack and kill any larvæ of the latter or of other scarabaeids that chanced to be exposed on the surface, and it is reasonable to suppose that they would do the same thing underground, an inference which is supported by the observation that rarely, if ever, were scarabaeid larvæ of any kind encountered in the vicinity of ant colonies.

In the junior writer's experience the most frequent enemies are certain mites which attach themselves to the body surface. That these mites derive any nourishment from their host the writers are not prepared to assert. Nathan Banks, then of the Bureau of Entomology, to whom specimens of the mites were sent and who determined them as the hypopus stage of *Rhizoglyphus phylloxerae* Riley, asserts that they are saprophytes, feeding upon decaying vegetable matter. Whatever may be the normal feeding habits of the mites, it is the experience of the writers as well as of other investigators (Davis, 5; Smyth, 12) that the presence of these and other mites is highly detrimental to the grubs and also to the pupæ. Upon adults they appear to have little effect. The junior writer has observed adults almost literally encrusted with mites and apparently none the worse for the presence of their uninvited guests. Larvæ and pupæ are more susceptible, however, and it is the opinion of the writers that the high mortality in the larvæ and pupæ in the breeding cages and boxes was due in large measure to the mites. Larvæ have been found in the field with the mites attached to them, so that it is not alone in the breeding boxes that they are attacked.

At Tappahannock in the summer of 1915 these mites were very numerous and troublesome, but in the following year they had all but disappeared. Possibly such fluctuations in the numbers of the mites from year to year may be one of the factors in determining the rather sporadic and irregular manner in which destructive outbreaks of *E. rugiceps* appear to occur.

The larvæ and pupæ were found occasionally to be infested with minute whitish nematode worms. Usually these were observed on the surface, where they tended to congregate in the intersegmental furrows, but sometimes an identical or closely similar type of nematode could be seen, through the transparent body wall, moving about in the body fluid.

There are unquestionably two species of true parasites, one of which, a dextiid fly, W. R. Walton determined as *Megapariopsis opaca* Coq. The maggot of this fly feeds within the body of the larva until it is ready to form the puparium. Those reared by the writers bored their way out of the host shortly before changing to puparia.

The other parasite was a hymenopterous insect, of which none was reared to the adult stage. For this reason the specific identity of the parasite was not determined, but it closely resembles *Tiphia inornata* Say, the best known probably of all the enemies of *Phyllophaga* as described by Davis (4, p. 15) and Smyth (12). The young of this parasite is a thick white maggot, which during the time it is feeding lies in a transverse position on the dorsum of its host

immediately behind the head. The few specimens observed by the junior writer in tin salve boxes failed to give up adults. In the field, however, he has found on several occasions the cocoons of what he is inclined to think is the same form. These resemble in general the cocoons of *Tiphia* and, like the latter, are characterized by having the head shield of the host attached at one end. In a number of cases the head shield of *E. rugiceps* has been found attached to these cocoons, but adults were not reared from them.

All stages of *E. rugiceps*, but more especially the larva and pupa, are subject to infection by a fungus, specimens of which were identified by Dr. A. T. Speare, formerly of the Bureau of Entomology, as *Metarhizium anisopliae*.

CONTROL MEASURES

As has been shown, *Euethola rugiceps* breeds mainly in low, moist, poorly drained areas that have been allowed to remain as waste or pasture lands for a considerable period of time. In fact under normal conditions these are apparently the only places where the pest breeds in sufficient numbers to constitute a menace to corn-fields. Land that is kept in a high state of cultivation, with frequent and systematic rotation of crops, furnishes an unfavorable breeding ground for this beetle. Very few beetles reach maturity in cultivated fields; occasionally quite a number may be found breeding in temporary pastures or hay fields. The numbers of beetles developing in such places, however, are insignificant compared with those breeding in the normal habitat of the species.

ELIMINATION OF WASTE LANDS AND OLD PASTURES

Knowing these facts, by far the most important means of control naturally suggests itself, namely, the elimination of all old waste and pasture lands. All such lands should be thoroughly drained and included in the regular system of rotation practiced for the remainder of the farm. If it seems most desirable to retain these lands for pasture, they should be broken up and reseeded every few years. This would be advisable if only as a matter of good farming, since in localities troubled with this pest pastures will become overgrown with weeds of many kinds in a few years at the expense of the more valuable grasses. The practices suggested will not only destroy the chief breeding grounds of the pest, but will make these lowlands more productive and profitable.

Such pasture lands when broken up should not be planted to corn the first year. As no other cultivated crop is injured by *Euethola rugiceps*, some other crop can be substituted. The following year corn may be planted, as there is but a single generation of the beetles a year.

PASTURING WITH HOGS

When old waste or pasture lands can not be drained conveniently and included in the rotation, the probability of injury resulting from the presence of these breeding grounds may be eliminated largely by pasturing hogs on such land every year, at least during August and September. The hogs will root out the grubs industriously.

EARLY PLANTING

Since the depredations of the beetles appeared to occur mostly during May and June in 1914 and 1915, experiments were conducted in 1916 at Tappahannock to learn something of the possibilities of control by early planting. The earliest plantings were on April 7, and plantings continued at two-week intervals until June 19. Though the test was too short to be conclusive, the results indicated that May plantings suffered the greatest injury from *Euetheola rugiceps*.

CHANGE OF ROTATION

As previously stated, corn should not be planted after sod where there is the prospect of injury from the beetle. Besides the rough-headed corn stalk-beetle, sodworms and cutworms are always a source of danger to corn planted on old sod land. Therefore any system of rotation which obviates the necessity of following sod with corn helps to avoid several serious insect pests.

FERTILIZERS

The application of barnyard manure or commercial fertilizers is beneficial, because growth is hastened and the corn plants are thus enabled more quickly to reach a state where they are less likely to be injured seriously.

HAND PICKING

Hand picking is at best only a temporary expedient and in most cases very expensive. When a field of growing corn has become infested, however, there is no other hope of relief. Cheap labor sometimes may be employed to collect and destroy the beetles found in young corn. This work should be done principally when the corn is being either plowed or thinned.

LATE SUMMER PLOWING

The rough-headed corn stalk-beetle enters the pupa stage during the latter part of August and it is in this stage that the insect is most easily destroyed, the least disturbance being sufficient to kill the pupæ. For this reason, wherever possible, sod lands should be plowed the last week in August or the first week in September for Virginia but earlier than this for more southern localities.

SUMMARY OF CONTROL MEASURES

Eliminate all old pastures or waste land, especially low, moist areas, and drain such lands thoroughly.

Pasture hogs in waste or pasture lands that can not be conveniently drained and cropped.

Plant corn early, say about April 20 for tidewater Virginia, and earlier for more southerly localities.

Give liberal applications of barnyard manure or commercial fertilizers whenever practical.

Employ cheap labor to collect and destroy the beetles when a field first shows injury.

Do not allow corn to follow sod if possible to avoid it.

Plow sod land in late summer and early fall in order to destroy the pupæ of the rough-headed corn stalk-beetle.

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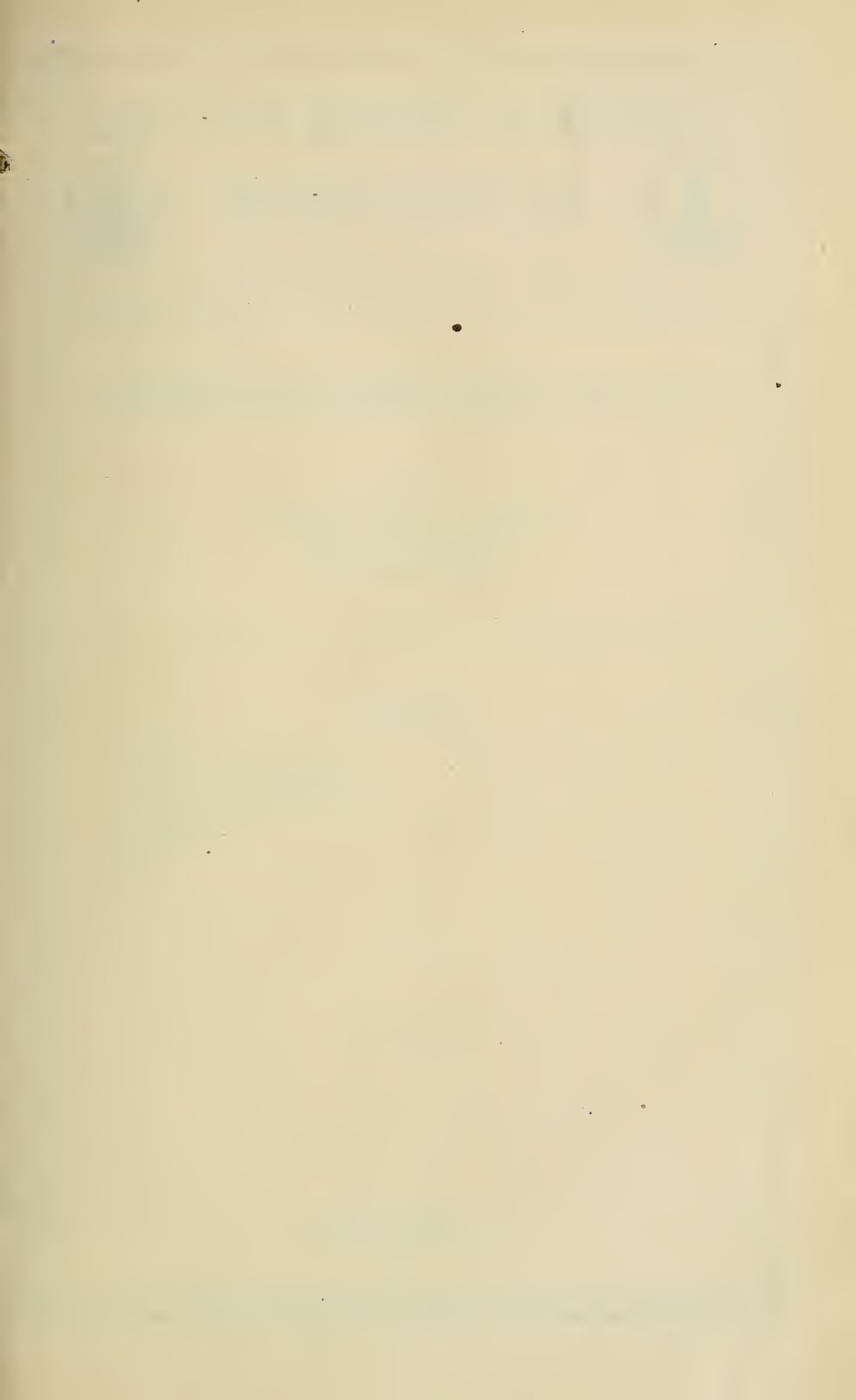
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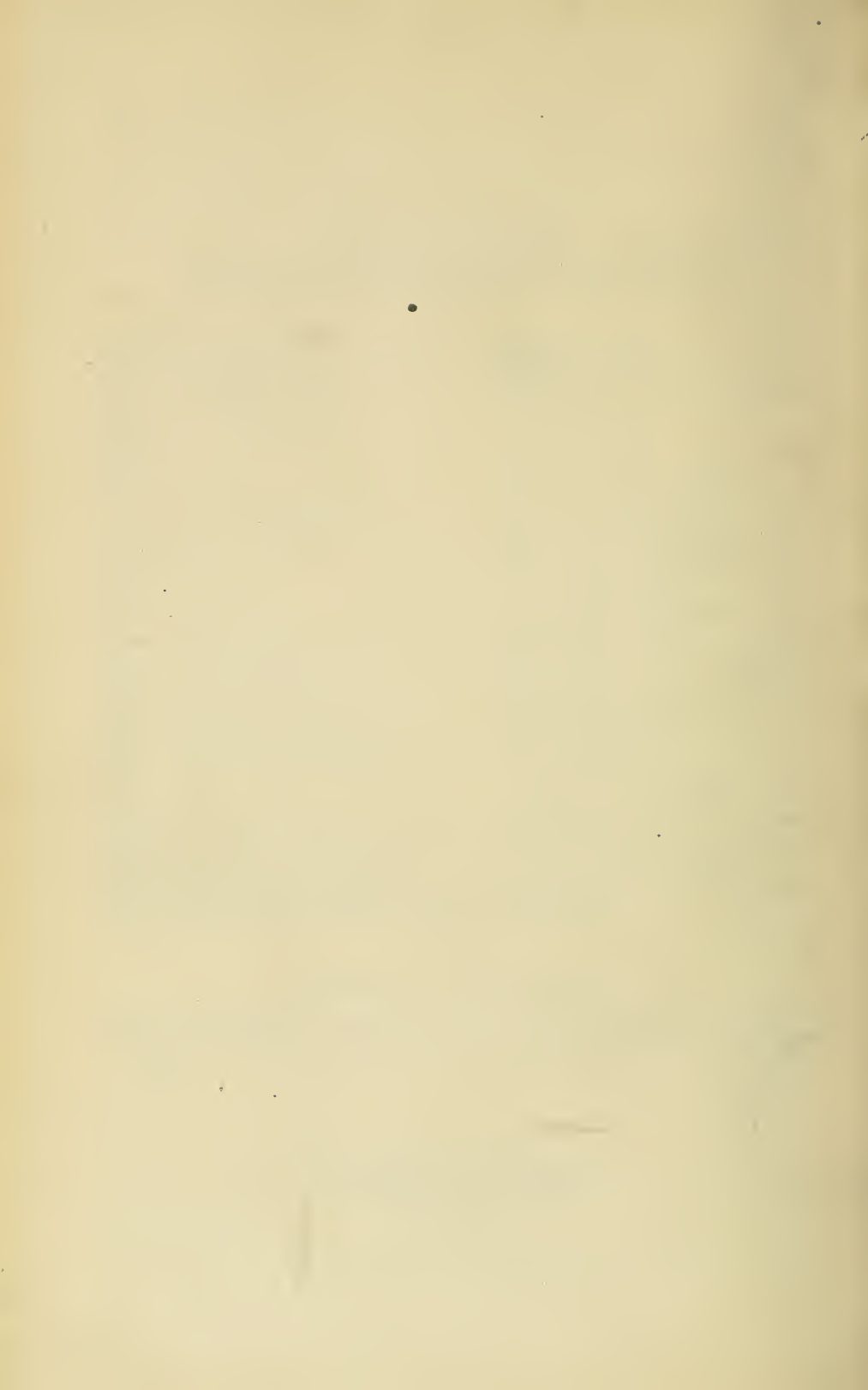
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UNITED STATES DEPARTMENT OF AGRICULTURE



DEPARTMENT BULLETIN No. 1268



Washington, D. C.



October 16, 1924

RETURNS FROM BANDED BIRDS, 1920 TO 1923

By

FREDERICK C. LINCOLN, Associate Biologist

Division of Biological Investigations

Bureau of Biological Survey

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INTRODUCTION

The marking of birds by means of numbered aluminum bands is resulting in the accumulation of information that will be valuable in solving many problems in ornithology. The experiment of Audubon, as long ago as 1803,¹ in banding a brood of phoebes is now well known, while the interesting and valuable results obtained by Dr. Paul Bartsch, in 1902, in his work with black-crowned night herons in the District of Columbia,² and by Dr. John B. Watson, in 1907, with sooty and noddy terns at Dry Tortugas, Fla.,³ have also been detailed in full.

ORGANIZED ACTIVITIES IN BIRD BANDING

For the credit of conceiving a broader scope for the banding method credit must be given in this country to P. A. Taverner and Dr. Leon J. Cole. Mr. Taverner, in 1903, distributed to interested persons a number of hand-made bands bearing the legend NOTIFY THE AUK NY, and a serial number. Comparatively few birds were thus banded, and only one return appears to have been recorded.⁴ Through the efforts of Doctor Cole, the New Haven Bird Club in 1908 issued a comparatively small series of bands, bearing the legend BOX Z. YALE STA. NEW HAVEN, CONN.; in 1909, the legend was changed to read NOTIFY THE AUK NEW YORK. The bands used by the New

¹ Audubon, John James. Ornithological biography, vol. 2, p. 126, 1834.

² Bartsch, Paul. Notes on the herons of the District of Columbia: Smiths. Misc. Col., vol. 45, pub. no. 1419, quart. Issue, vol. 1, pts. 1 and 2, pp. 104-111, pls. 32-33, 1904.

³ Watson, John B. The behavior of noddy and sooty terns: Pub. 103, Carnegie Inst. Washington, paper 7, pp. 187-225, pls. 1-11, March, 1909.

⁴ The Auk, vol. 23, p. 232, April, 1906.

Haven club were the first to be issued by any ornithological club in this country. Somewhat more than 5,000 of these bands were distributed during the first season after their adoption, and Doctor Cole, in commenting on the fact, expressed his satisfaction that "approximately one-fifth of these were used and are now [1909] being worn by a very considerable number of wild birds."⁴ His paper on the subject was presented at the meeting of the American Ornithologists' Union, in New York City, in November, 1909, and emphasized the need of a permanent organization.

The subject was again taken up at a dinner held at the Hotel Endicott on November 8, 1909, and the organization of the American Bird Banding Association was perfected at the meeting which followed. The legend on the bands was again changed, the new inscription reading NOTIFY A. M. MUSEUM, N. Y. (sic), or (on the smaller sizes) NOTIFY A. M. N. H., N. Y. Adequate funds for the purchase of bands and other supplies constituted a source of more or less difficulty, but through the activities of this association, and particularly through the untiring efforts of its secretary, Howard H. Cleaves, and the assistance of the Linnæan Society of New York (since April, 1911), the work was prosecuted until January, 1920. During this period an important paper was presented by S. Prentiss Baldwin which indicated the high character of the results that might be obtained from the systematic trapping and banding of birds.⁵

In January, 1920, the work of the American Bird Banding Association was formally taken over by the Biological Survey as an adjunct to its investigations. The importance of this method of obtaining information relative to the migrations and life histories of birds is being fully demonstrated.

Plans were at once formulated by the Biological Survey for the intensive development of the project, but putting them into full effect was delayed until an adequate supply of bands could be assured. A manufacturer was finally found after a long search, who was sufficiently interested to install and perfect the necessary machinery. With a supply of bands available to make a thorough study, the bird-banding project has been developed steadily through an increasing number of cooperators, whose work is done without compensation.

The work now bids fair to become one of the most effective means for gathering precise information relating to bird migration and to the life histories of many species. Studies conducted with many individuals of a species at different trapping stations—thereby checking the work of the different operators—are providing a wealth of indisputable information which will in some cases no doubt completely revolutionize some accepted beliefs. It is generally conceded that these results could be obtained in no way other than by the banding method as furthered by the establishment of numerous trapping stations.

⁴ Cole, Leon J. The tagging of wild birds; report of progress in 1909: *The Auk*, vol. 27, no. 2, p. 157, April, 1910.

⁵ Baldwin, S. Prentiss. Bird banding by means of systematic trapping: *Abstr. Proc. Linnæan Soc. New York*, no. 31, pp. 27-56, pls. 1-7, 1919.

REGIONAL BANDING ASSOCIATIONS

Because of the great difficulty of coordinating the activities of large numbers of cooperators in various parts of the United States and Canada, the expediency of grouping them into regional associations, each with its proper officers, was favorably considered. The plan at first contemplated was the allotment of territory along natural geographic lines as far as possible, although, unfortunately, it has been necessary to make the boundaries conform to political lines, because of the State permits that must be obtained. The system has been satisfactory, however, and under the guidance of experienced ornithologists the development of the local associations has been rapid.

Northeastern Bird Banding Association.—First of these local associations was the present Northeastern Bird Banding Association, originally organized as the New England Bird Banding Association, on January 17, 1922, the result of the interest and tireless energy of Laurence B. Fletcher, of Boston, Mass., who has since served in the capacity of secretary. E. H. Forbush, State ornithologist of Massachusetts, was elected the first president. The territory covered includes the New England States, the Maritime Provinces of Canada, and Quebec.

Inland Bird Banding Association.—The second regional organization to be launched was the Inland Bird Banding Association, formed on October 24, 1922, at the Chicago, Ill., meeting of the American Ornithologists' Union. S. Prentiss Baldwin, whose work in systematic trapping opened a new field of bird banding, has served continuously as president, and William I. Lyon, of Waukegan, Ill., a pioneer in the work, has served as secretary. This association is coordinating the work in the territory tributary to the Mississippi River, extending from the Allegheny Mountains to the Rocky Mountain States and British Columbia.

Banding Chapter, Cooper Ornithological Club.—The Cooper Ornithological Club next took an active interest in the subject. Because of the fact that the existing organization was devoted primarily to the study of western birds, it was not considered advisable to promote a separate association. A "Banding Chapter of the Cooper Club" was accordingly formed, with J. Eugene Law, of Altadena, Calif., as chairman. The territory covered by the chapter includes the entire Pacific coast area, including Alaska, together with the Rocky Mountain States.

Eastern Bird Banding Association.—With three organizations functioning, there remained unallotted only the territory on the Atlantic coast south of and including New York, and the Province of Ontario. It was accordingly considered important to form an association of the cooperators in this region. At a special meeting of the Linnæan Society of New York, held at the American Museum of Natural History on April 24, 1923, the subject was fully discussed and Mr. Baldwin was authorized and requested to take care of the preliminary arrangements. As a result, the Eastern Bird Banding Association has been organized, with Dr. Arthur A. Allen, of Cornell University, Ithaca, N. Y., as president, Mrs. J. E. Webster, of East Orange, N. J., as secretary, and Rudyerd Boulton, of the University of Pittsburgh, as executive secretary.

So great is the extent of the territory assigned to most of these regional associations that further subdivision will ultimately be necessary. This is being anticipated and will be accomplished when the cooperators in any geographic area become sufficiently numerous and leaders for new groups can be developed. There are already many station operators of experience who will, no doubt, be capable of furthering such activities.

RETURNS REPORTED TO THE BIOLOGICAL SURVEY

Facts relative to the 1,746 returns that were received by the Biological Survey during the period from January 1, 1920, to June 30, 1923, are set forth in this report in tabular form, in order that coop-

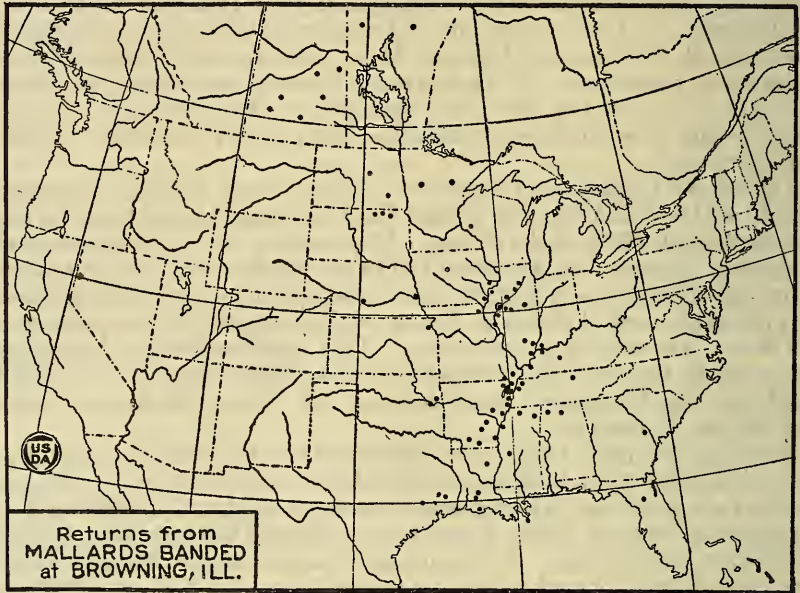
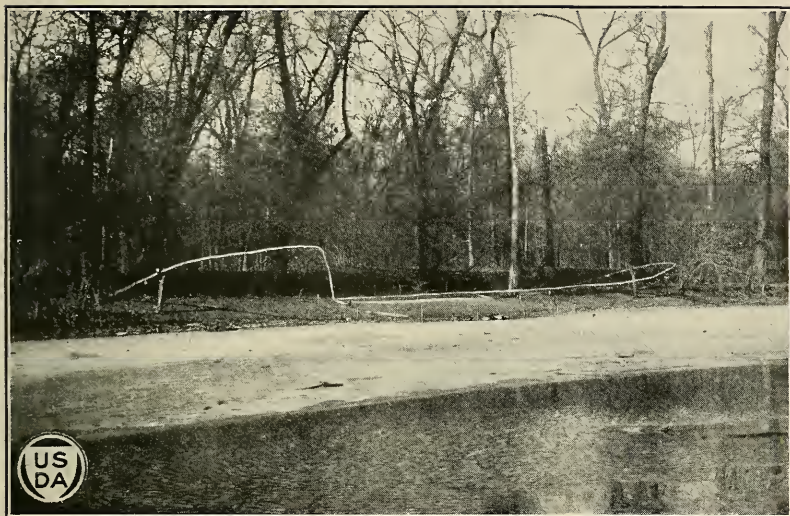


FIG. 1.—Localities from which bands have been returned that were attached to mallard ducks at the Sanganois Club, Browning, Ill., during the period February 28 to March 25, 1922, and September 27 to December 15, 1922. In the Mississippi Valley one spot on the map may indicate several returns. A study of the migration of this important game bird is receiving special treatment by means of the banding method and, as illustrated, information already received shows a dispersal from the point of banding over a vast region that extends from the coast of Texas and Louisiana north to central Manitoba and Saskatchewan, with an occasional mallard traveling east to the Atlantic coast.

erators and others interested may the more readily use the available information for present purposes and as a basis for further investigations. In addition, it is believed that the meager results obtained from the banding of some species will serve as a stimulus for those who may be sufficiently ingenious to devise new and effective contrivances for the capture of birds of these species in larger numbers.

The tables in this report are presented without discussion, for the reason that it is deemed inexpedient to attempt detailed comment for all groups when it is obvious that the material will permit a wide range of interpretation. This will depend not only upon the character of the returns obtained for different species, but also upon ecological, meteorological, and other factors that demand full consideration.



B24054

FIG. 1.—SPRING-POLE TRAP

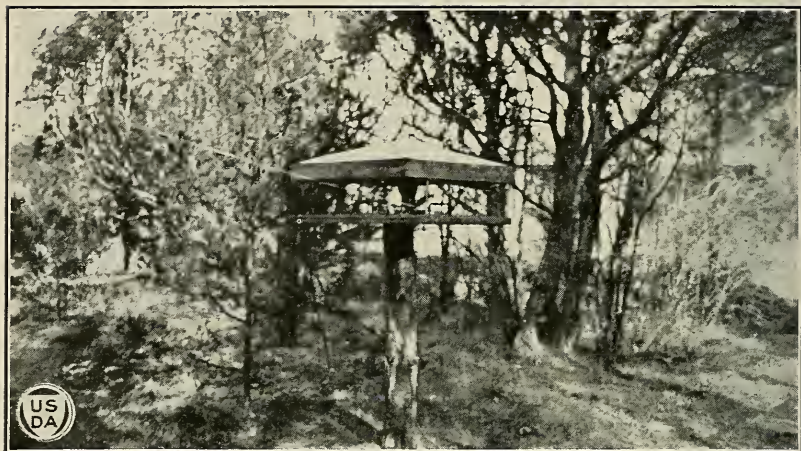
Duck station at Cuivre Island, Mo., operated by L. V. Walton



B24074

FIG. 2.—AUTOMATIC PEN-TRAP

Duck station maintained at the Sanganois Club, Browning, Ill., by the writer. The trap contained 93 mallards, pintails, and black ducks when this picture was taken



B2437

FIG. 1.—COLLAPSIBLE DROP-TRAP

Used under cover for protection from the weather, at the station of Richard B. Harding, Cohasset, Mass.



B2438

FIG. 2.—COLLAPSIBLE DROP-TRAP (CLOSE VIEW)

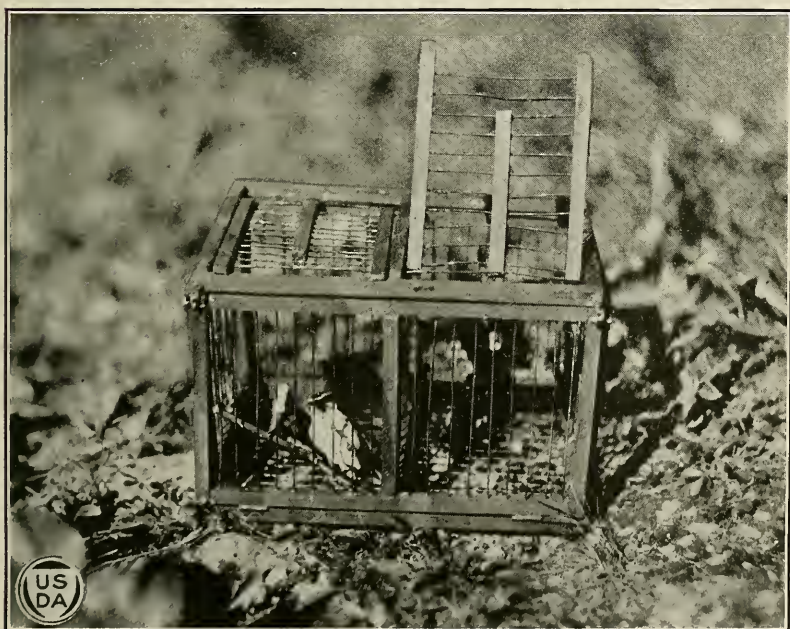
The trap illustrated above, with cover removed to show food hopper, by means of which a constant supply of bait is maintained during days when the trap is not operated. At such times birds are free to enter and leave at will



B2439

FIG. 1.—TREE-TRUNK TRAP

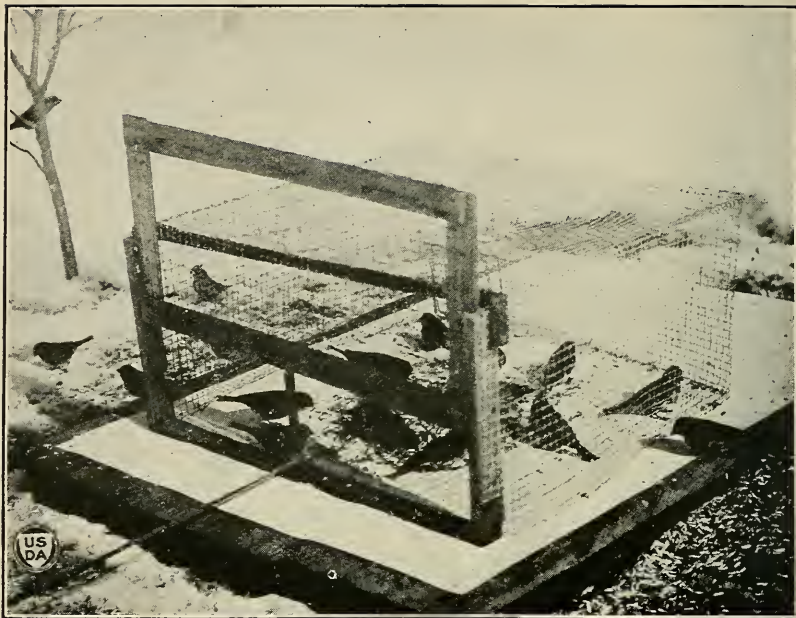
Operated at station of Richard B. Harding, Cohasset, Mass.



B2367

FIG. 2.—FOLDING WARBLER-TRAP

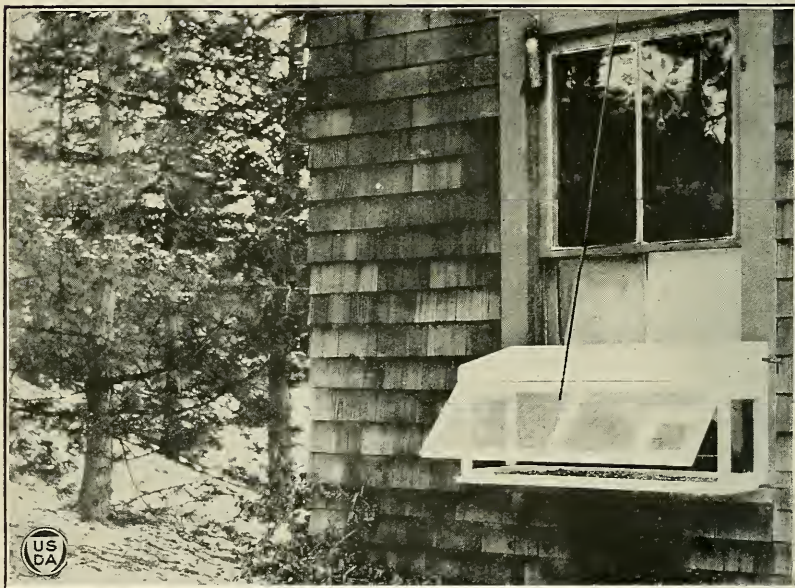
Used by T. Donald Carter and R. H. Howland in conducting studies with Brewster warblers.
The trap contains an adult male of this species



B2436M

FIG. 1.—SLIDING-DOOR TRAP

Operated at the station of B. S. Bowdish, Demarest, N. J.; 119 purple finches were taken in this trap on a single day



B32435M

FIG. 2.—WINDOW FEEDING-STATION AND TRAP

A protected window trapping station operated by R. E. Horsey, at Highland Park, Rochester, N. Y.

For instance, what might prove an excellent method of treatment for returns from the mallard duck (Fig. 1) would not be applicable in the case of the song sparrow.

With a sufficient accumulation of information from different parts of the country, it will be possible eventually to prepare reports which will constitute distinct contributions to our knowledge of the species involved.⁶ The number of recruits to this new method of ornithological research is constantly increasing, and it is gratifying to note that many cooperators are directing their activities toward the solution of definite problems concerning certain species.

EXPLANATION OF TABLES

The various species are presented in the order of the "A. O. U. Check-List."⁷ The records under individual species are arranged numerically under the names of the operators, grouped alphabetically by States, which also are in alphabetical order. Thus under "Tree sparrow," the table begins with returns from birds banded in Connecticut by cooperators listed alphabetically. This is followed by Illinois and Massachusetts, with the returns from the cooperators in the respective States, similarly arranged. This method of treatment has been adopted because any studies based on this material should place initial emphasis upon the locality (State or Province) where the birds were originally banded.

Numbers preceded by an asterisk (*) are those of the American Bird Banding Association, all others being those of the Biological Survey. These records have been obtained mostly from birds marked since January, 1920, as the remnant of the association bands have been issued by the Biological Survey. In a few cases, however, it has appeared advisable to give the complete history of a bird that has yielded a series of returns of special interest, and in these instances return records received by the association prior to 1920 also are included.

Numbers preceded by a dagger (†) indicate recently banded birds found dead at or near the place of banding. Unusually late dates in these "short-time returns" are often due to the fact that the carrier was not found until some time after its death.⁸ Following is a list of known causes of such deaths:

Due to—	Due to—
Cats.	Blue jays.
Shrikes.	Hunters.
Red squirrels.	Capture in—
Ground squirrels.	Herring net.
Weasels.	Fish trap.
Rats.	Muskrat trap.
Owls (species?).	Saturation of plumage with fuel oil.
Sparrow hawks.	Crowding of fledglings out of nest by
Cooper hawks.	cowbirds.
"Grass" snakes.	Inclement weather.
Gopher snakes.	Desertion of fledglings by parents.
Black snakes.	Accidents due to traps or operators.
"Hawk or gull."	

⁶ One preliminary report of the migrations of certain ducks, as deduced from banding returns, has been prepared by the writer (Trapping ducks for banding purposes: *The Auk*, vol. 39, pp. 322-334, pls. 11-14, map, 1922), and he has in progress more elaborate communications dealing with these birds, together with the herring gull and Caspian tern.

⁷ Check-List of North American Birds of the American Ornithologists' Union, third edition (revised), 1910.

⁸ Martin No. 104232 (p. 45) was found dead when the colony house was cleaned out—long after the parents had left.

Of death-dealing agencies, by far the most numerous are cats and shrikes, with squirrels of various species next. Accidents at trapping stations that may be attributed to carelessness, inexperience, or improperly constructed traps have been remarkably few. Naturally some accidents would occur where inexperienced persons began handling large numbers of small birds, caught in traps which in some cases were either purely experimental or crudely constructed. The fact that such mishaps have been so few offers abundant justification of the bird-banding method and shows the care and gentleness exercised by cooperators. Information as to the cause of the death of banded birds when forwarded to the Biological Survey yields interesting light on the subject of bird mortality and its causes and is thus available for study purposes.

Symbols and abbreviations used in these tables, in addition to the asterisk (*) and the dagger (†), already explained, are as follows: ♂, male bird; ♀, female; juv., young (juvenile); im., immature.

TABLES OF RETURNS

Loon: *Gavia immer*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
201486	-----	H. A. McGraw	Altoona, Pa.-----	Apr. 30, 1923	May 27, 1923	Balmy Beach, Simcoe County, Ontario.

Glaucous-winged Gull: *Larus glaucescens*

200990	juv.	Theed Pearse.	Gulf of Georgia, British Columbia.	July 30, 1922	Feb. 16, 1923	Pacific coast, 86 mi. N. of Vancouver, British Columbia.
200994	juv.	do.....	do.....	do.....	Dec. 15, 1922	Redonda Bay, British Columbia.

Herring Gull: *Larus argentatus*

100633	juv.	Ernest Joy....	Grand Manan, New Brunswick.	Aug. 16, 1921	Jan. 4, 1922	Jamaica Bay, N. Y.
100646	juv.	do.....	do.....	do.....	Oct. 18, 1921	Maceo Bay, Charlotte County, New Brunswick.
100698	juv.	do.....	do.....	Aug. 18, 1921	Apr. 9, 1922	San Antonio Bay, Tex.
100700	juv.	do.....	do.....	do.....	June 18, 1922	Rockaway Point, N. Y.
*25386	juv.	Wm. Pepper..	Little Duck Island, Me.	July 19, 1915	Aug. 1920	Cape Porpoise, Conn
202213	juv.	W. S. McCrea.	St. James, Mich.	July 16, 1922	Jan. 18, 1923	Wickliffe, Ky.
202237	juv.	do.....	do.....	do.....	Nov. 30, 1922	Ennis, Tex.
202248	juv.	do.....	do.....	do.....	Jan. 12, 1923	Brunswick, Ga.

Ring-billed Gull: *Larus delawarensis*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
5553	juv.	Francis Harper.	Lake Athabaska, Alberta.	June 28, 1920	Oct. 2, 1920	Lesser Slave Lake, Alberta.

Caspian Tern: *Sterna caspia imperator*

202257	juv.	W. S. McCrea.	St. James, Mich.	July 28, 1922	Sept. 24, 1922	Traverse City, Mich.
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Common Tern: *Sterna hirundo*

*1258	juv.	J. C. Phillips.	Eastern Egg Rock, Me.	July 3, 1913	Aug. 1917 ¹	Niger River Delta, South Nigeria, West Africa.
*54886	-----	F. P. Cook-----	Brigantine Island, N. J.	July 27, 1920	May 20, 1922	Paria Bay, Blanchisseuse, Trinidad.
104872	juv.	Edwin Beaupre.	Bay of Quinte, Ontario.	July 14, 1922	Aug. 15, 1922	Rochester, N. Y. (12 mi. W.).

Gannet: *Moris bassana*

207105	juv.	H. L. Stoddard.	Bonaventure Island, Quebec.	July 31, 1922	May 2, 1923	Alberton, Prince Edward Island.
207236	juv.	-----do-----	-----do-----	-----do-----	Sept. 15, 1922	Casco Bay, Me.
207269	juv.	-----do-----	-----do-----	-----do-----	Nov. 27, 1922	Neils Harbor, Nova Scotia.

White Pelican: *Pelecanus erythrorhynchos*

100553	juv.	A. F. Walther.	Morse, Saskatchewan.	Oct. 22, 1921	Oct. 27, 1921	Lindsay, S. Dak.
†201809	juv.	H. B. Ward...	Yellowstone Lake, Wyo.	July 26, 1922	-----	Yellowstone Lake, Wyo.
201815	juv.	-----do-----	-----do-----	-----do-----	Oct. 9, 1922	Swan Lake, Idaho.
201820	juv.	-----do-----	-----do-----	-----do-----	Sept. 1922	Red Rock Lake, Mont.
†201826	juv.	-----do-----	-----do-----	-----do-----	-----	Yellowstone Lake, Wyo.
†201831	juv.	-----do-----	-----do-----	-----do-----	-----	Do.
201835	juv.	-----do-----	-----do-----	-----do-----	Oct. 5, 1922	Garland, Utah.
†201841	juv.	-----do-----	-----do-----	-----do-----	-----	Yellowstone Lake, Wyo.
201843	juv.	-----do-----	-----do-----	-----do-----	Feb. 26, 1923	Otatitlan, Mexico.
201850	juv.	-----do-----	-----do-----	-----do-----	Oct. 1, 1922	Idaho Falls, Idaho (40 mi. NW.).
201860	juv.	-----do-----	-----do-----	-----do-----	Oct. 11, 1922	Sterling, Utah.
201873	juv.	-----do-----	-----do-----	-----do-----	Oct. 10, 1922	Aurora, Utah.

¹ Reported under date of Nov. 18, 1920.

Mallard: *Anas platyrhynchos*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
†101043	♀	A. M. Shields	San Francisco, Calif.	Sept. 6, 1922	Dec. 31, 1922	San Francisco, Calif.
†101045	♂	do	do	do	Nov. 5, 1922	Do.
102401	♂	F. C. Lincoln	Browning, Ill.	Mar. 3, 1922	Jan. 18, 1923	Big Lake, Ark.
102402	♂	do	do	Mar. 5, 1922	Nov. 19, 1922	Gainesville, Fla. (5 mi. N.).
102415	♂	do	do	Mar. 6, 1922	Nov. 13, 1922	Hamilton County, Iowa.
102421	♂	do	do	do	Oct. 7, 1922	Luck Lake, Saskatchewan.
102422	♂	do	do	do	Dec. 15, 1922	Browning, Ill.
102425	♀	do	do	do	Dec. 2, 1922	Grand Island, Ill.
102426	♂	do	do	do	Oct. 4, 1922	Quill Lake, Saskatchewan.
102442	♂	do	do	Mar. 7, 1922	Nov. 27, 1922	Bennett, Iowa.
102454	♀	do	do	do	Sept. 20, 1922	Leola, S. Dak. (16 mi. NW.).
102470	♀	do	do	do	Nov. 10, 1922	Leavenworth, Kans.
102495	♀	do	do	Mar. 8, 1922	Nov. 22, 1922	Chillicothe, Ill. (3 mi. E.).
102516	♀	do	do	Mar. 9, 1922	Dec. 2, 1922	Henry, Ill.
102520	♂	do	do	do	Dec. 18, 1922	Memphis, Tenn. (20 mi. S.).
102524	♂	do	do	do	Nov. 15, 1922	Henderson County, Ill.
102534	♂	do	do	do	Nov. 1, 1922	Ramsey County, N. Dak.
102546	♂	do	do	do	Dec. 25, 1922	Hull, Tex.
102556	♀	do	do	Mar. 10, 1922	Feb. 24, 1923	Kennett, Mo.
102572	♂	do	do	do	Dec. 29, 1922	Bath, Ill. (10 mi. S.).
102576	♂	do	do	do	Dec. 10, 1922	Pass a Loutre, La.
102590	♂	do	do	do	Nov. 29, 1922	Henderson County, Ill.
102591	♂	do	do	do	Nov. 6, 1922	Jamestown, N. Dak. (11 mi. NE.).
102601	♂	do	do	do	Nov. 15, 1922	Moon Lake, Ark.
102610	♂	do	do	do	Nov. 13, 1922	Welsh, La. (8 mi. NW.).
102611	♂	do	do	do	Dec. 26, 1922	Sangamon River, Ill.
102632	♂	do	do	Mar. 11, 1922	Nov. 15, 1922	Burlington, Iowa (10 mi. S.).
102633	♀	do	do	do	Apr. 22, 1922	Buchanan, Saskatchewan.
102634	♀	do	do	do	Jan. 27, 1923	Checotah, Okla.
102635	♀	do	do	do	Sept. 27, 1922	Petersburg, Ill. (4 mi. N.).
102659	♀	do	do	do	Dec. 15, 1922	Chandlerville, Ill.
102665	♀	do	do	do	Oct. 25, 1922	Browning, Ill.
102678	♂	do	do	do	Nov. 11, 1922	Mason County, Ill.
102685	♀	do	do	do	Dec. 11, 1922	Fulton County, Ill.
102691	♂	do	do	do	Dec. 8, 1922	Burlington, Iowa (6 mi. S.).
102701	♀	do	do	do	Dec. 28, 1922	Beardstown, Ill.
102704	♀	do	do	do	Dec. 12, 1922	De Witt, Ark. (25 mi. S.).
102706	♀	do	do	do	Nov. 25, 1922	Alexandria, Mo.
102707	♂	do	do	do	Nov. 12, 1922	Claremont, S. Dak.
102709	♀	do	do	do	Dec. 19, 1922	Havana, Ill. (5 mi. NE.).
102714	♂	do	do	do	Nov. 29, 1922	Lake Concordia, Miss.
102718	♀	do	do	do	Sept. 16, 1922	Herman, Minn. (8 mi. SE.).
102746	♂	do	do	Mar. 12, 1922	do	Leola, S. Dak. (8 mi. NW.).
102755	♂	do	do	do	Nov. 9, 1922	Lexington, Nebr. (7 mi. SW.).

Mallard—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
102794	♀	F. C. Lincoln	Browning, Ill.	Mar. 13, 1922	(?)	Sheho, Saskatchewan (6 mi. N.).
102804	♂	do.	do.	do.	Nov. 11, 1922	Omaha, Nebr.
102832	♂	do.	do.	Mar. 14, 1922	Sept. 15, 1922	Seward, Saskatchewan (2 mi. S.).
102843	♂	do.	do.	do.	Jan. 10, 1923	Desha County, Ark.
102853	♀	do.	do.	do.	Jan. 13, 1923	Pecan Island, La.
230003	♀	do.	do.	Nov. 9, 1922	Nov. 22, 1922	Snicarte, Ill.
230005	♂	do.	do.	Nov. 10, 1922	Dec. 9, 1922	Crane Lake, Ill.
230012	♂	do.	do.	Nov. 12, 1922	Nov. 12, 1922	Beardstown, Ill. (9 mi. NE.).
230013	♂	do.	do.	do.	Dec. 20, 1922	Bath, Ill.
230016	♂	do.	do.	do.	Dec. 4, 1922	Bath, Ill. (3 mi. S.).
230018	♂	do.	do.	do.	Dec. 3, 1922	Browning, Ill.
230020	♀	do.	do.	do.	Dec. 2, 1922	Snicarte, Ill. (3 mi. SW.).
230030	♂	do.	do.	Nov. 13, 1922	Nov. 21, 1922	Bath, Ill.
230043	♂	do.	do.	Nov. 16, 1922	Jan. 23, 1923	Reelfoot Lake, Tenn.
230049	♂	do.	do.	do.	Dec. 9, 1922	Bath, Ill. (5 mi. S.).
230050	♂	do.	do.	do.	Dec. 26, 1922	Castalian Springs, Tenn.
230051	♂	do.	do.	do.	Dec. 9, 1922	Crane Lake, Ill.
230054	♂	do.	do.	do.	Dec. 15, 1922	Sangamon River, Ill.
230061	♀	do.	do.	do.	Nov. 22, 1922	Reelfoot Lake, Tenn.
230068	♀	do.	do.	do.	Nov. 27, 1922	Bath, Ill.
230078	♂	do.	do.	Nov. 17, 1922	Dec. 28, 1922	Near Wisner, La.
230080	♂	do.	do.	do.	Nov. 19, 1922	Ill. R., Frederick, Ill. (3 mi. N.).
230082	♂	do.	do.	do.	Nov. 21, 1922	Cass County, Ill.
230083	♂	do.	do.	do.	Jan. 8, 1923	Jennings, La. (6 mi. NE.).
230091	♂	do.	do.	do.	Nov. 30, 1922	Saidora, Ill.
230094	♂	do.	do.	do.	Dec. 23, 1922	Chandlerville, Ill.
230098	♂	do.	do.	do.	Dec. 2, 1922	Do.
230100	♂	do.	do.	do.	Nov. 27, 1922	Snicarte, Ill.
230102	♂	do.	do.	do.	Dec. 20, 1922	Havana, Ill.
230104	♂	do.	do.	do.	Nov. 21, 1922	Beardstown, Ill.
230107	♂	do.	do.	do.	Dec. 28, 1922	Uniontown, Ky. (10 mi. S.).
†230110	♂	do.	do.	do.	Nov. 17, 1922	Browning, Ill.
†230116	♀	do.	do.	do.	do.	Do.
230119	♀	do.	do.	do.	Nov. 18, 1922	Bader, Ill.
230123	♀	do.	do.	do.	Dec. 27, 1922	Beardstown, Ill. (8 mi. NE.).
230124	♀	do.	do.	do.	do.	Beardstown, Ill.
230127	♀	do.	do.	do.	Dec. 9, 1922	Beardstown, Ill. (11 mi. SW.).
230128	♀	do.	do.	do.	Nov. 22, 1922	Crane Lake, Ill.
230131	♀	do.	do.	do.	Nov. 27, 1922	Saidora, Ill. (1½ mi. SW.).
230132	♀	do.	do.	do.	Dec. 16, 1922	Beardstown, Ill.
230133	♀	do.	do.	do.	Dec. 6, 1922	Arenzville, Ill. (12 mi. N.).
230150	♀	do.	do.	Nov. 18, 1922	Dec. 1, 1922 ²	Beardstown, Ill. (6 mi. E.).
†230162	♂	do.	do.	do.	Nov. 28, 1922	Browning, Ill.
230165	♂	do.	do.	do.	Dec. 17, 1922	Illinois River, Ill.
230170	♂	do.	do.	do.	Dec. 21, 1922 ²	Crane Lake, Ill.
230174	♂	do.	do.	do.	Nov. 19, 1922	Schuyler County, Ill.
230178	♂	do.	do.	do.	Nov. 26, 1922	Bath, Ill.

² Date approximate.

Mallard—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
230181	♂	F. C. Lineoln.	Browning, Ill.	Nov. 18, 1922	Dec. 15, 1922	Almyra, Ark.
†230185	♂	do	do	do	Nov. 26, 1922	Browning, Ill. (3 mi. S.).
†230200	♀	do	do	do	Dec. 30, 1922	Browning, Ill. (1 mi. S.).
230202	♀	do	do	do	Nov. 29, 1922	Rice Lake, Ill.
230205	♀	do	do	do	Nov. 22, 1922	Beardstown, Ill.
230213	♂	do	do	Nov. 19, 1922	Nov. 30, 1922	Illinois River, Ill.
230217	♂	do	do	do	Dec. 10, 1922	Bath, Ill.
†230220	♂	do	do	do	Dec. 2, 1922	Browning, Ill. (3½ mi. N.).
230229	♀	do	do	do	Dec. 1, 1922	Bath, Ill.
230239	♂	do	do	Nov. 20, 1922	Nov. 24, 1922	Do.
230240	♂	do	do	do	Nov. 30, 1922	Saidora, Ill.
230253	♂	do	do	do	Dec. 28, 1922	Grand Island, Ill.
230256	♂	do	do	do	Nov. 27, 1922	Bath, Ill.
230262	♀	do	do	do	Jan. 26, 1923	Sequah County, Okla.
†230265	♀	do	do	do	Dec. 6, 1922	Browning, Ill.
230268	♀	do	do	do	do	Mason County, Ill.
230269	♀	do	do	do	Nov. 23, 1922	Crane Lake, Ill.
230272	♀	do	do	do	Dec. 25, 1922	Beardstown, Ill.
230273	♀	do	do	do	Dec. 17, 1922	Beardstown, Ill. (4½ mi. NE.).
†230275	♀	do	do	do	Nov. 29, 1922	Browning, Ill.
230276	♀	do	do	do	Dec. 10, 1922	Bath, Ill. (4 mi. S. W.).
230281	♀	do	do	do	Nov. 21, 1922	Pecan Orchard (6 mi. NE. of Beardstown, Ill.).
230283	♀	do	do	do	Jan. 10, 1923	Wheeler, Miss.
230287	♀	do	do	do	Jan. 5, 1923	Chidester, Ark.
230288	♀	do	do	do	Dec. 1, 1922	Crane Lake, Ill.
230294	♂	do	do	do	Nov. 24, 1922	Beardstown, Ill.
230300	♂	do	do	do	Dec. 14, 1922	Bath, Ill.
†230304	♂	do	do	do	Dec. 16, 1922	Browning, Ill.
230308	♂	do	do	do	Dec. 14, 1922	Snicarte, Ill.
230309	♂	do	do	do	Dec. 27, 1922	Schuyler County, Ill.
†230314	♂	do	do	do	Dec. 24, 1922	Browning, Ill.
230316	♂	do	do	do	Nov. 26, 1922	Beardstown, Ill. (7 mi. N.).
230318	♂	do	do	do	Jan. 31, 1923	Saratoga, Tex.
230322	♂	do	do	do	Dec. 12, 1922	Bath, Ill.
230327	♀	do	do	do	Jan. 18, 1923	De Valls Bluff, Ark.
230332	♀	do	do	do	Nov. 23, 1922	Illinois River, Ill.
†230336	♀	do	do	do	Nov. 25, 1922	Browning, Ill.
230343	♂	do	do	Nov. 21, 1922	Nov. 23, 1922	Havana, Ill. (10 mi. N.).
230345	♂	do	do	do	Dec. 7, 1922	Mason County, Ill.
†230346	♂	do	do	do	Nov. 30, 1922	Browning, Ill.
†230347	♂	do	do	do	Dec. 2, 1922	Do.
230350	♂	do	do	do	Jan. 21, 1923	Canton, Miss.
230354	♂	do	do	do	Nov. 30, 1922	Beardstown, Ill.
230356	♂	do	do	do	Dec. 12, 1922	Crane Lake, Ill.
230357	♂	do	do	do	Dec. 2, 1922	Sheldons Grove, Ill.
†230363	♂	do	do	do	Nov. 24, 1922	Browning, Ill.
230367	♀	do	do	do	Dec. 6, 1923	Beardstown, Ill. (9 mi. NE.).
†230368	♀	do	do	do	Nov. 27, 1922	Browning, Ill. (4 mi. S.).
230373	♀	do	do	do	Dec. 30, 1922	Snicarte, Ill.
230396	♀	do	do	Nov. 22, 1922	Dec. 7, 1922	Bath, Ill. (6 mi. S.).
230403	♀	do	do	do	Dec. 20, 1922	Bath, Ill.
†230404	♀	do	do	do	Nov. 24, 1922	Browning, Ill.
†230408	♀	do	do	do	Dec. 23, 1922	Browning, Ill. (1 mi. S.).
†230409	♀	do	do	do	Nov. 23, 1922	Browning, Ill.
230411	♀	do	do	do	Jan. 15, 1923	Big Lake, Ark.

Mallard—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
230414	♀	F. C. Lincoln	Browning, Ill.	Nov. 22, 1922	Nov. 24, 1922	Beardstown, Ill.
230415	♂	do	do	do	Dec. 15, 1922	Mason County, Ill.
230419	♂	do	do	do	Nov. 24, 1922	Beardstown, Ill.
230440	♀	do	do	do	Nov. 27, 1922	Do.
†230451	♀	do	do	do	Nov. 24, 1922	Browning, Ill.
230457	♂	do	do	do	Dec. 18, 1922	Snicarte, Ill.
230459	♂	do	do	do	Dec. 8, 1923	Huntsville, Ala.*
230466	♂	do	do	do	Nov. 24, 1922	Beardstown, Ill.
230475	♂	do	do	do	Dec. 11, 1922	Havana, Ill.
230476	♂	do	do	do	Dec. 25, 1922	Holly Springs, Miss. (8 mi. E.).
230488	♂	do	do	do	Dec. 16, 1922	Crane Lake, Snicarte, Ill. (near).
†230508	♂	do	do	do	Dec. 1, 1922	Browning, Ill.
†230511	♂	do	do	do	Dec. 6, 1922	Do.
230512	♂	do	do	do	Nov. 25, 1922	Beardstown, Ill. (9 mi. NE.).
230516	♂	do	do	do	Nov. 30, 1922 ²	Snicarte, Ill.
230531	♂	do	do	do	Jan. —, 1923	Burke County, Ga.
†230533	♂	do	do	do	Nov. 24, 1922	Browning, Ill. (10 mi. N.).
†230534	♂	do	do	do	Dec. 30, 1922	Browning, Ill.
230544	♀	do	do	do	Dec. 25, 1922	Beardstown, Ill.
230546	♀	do	do	do	Nov. 25, 1922	Do.
†230547	♀	do	do	do	Dec. 18, 1922	Browning, Ill.
†230552	♀	do	do	do	Dec. 1, 1922	Do.
†230553	♀	do	do	do	Dec. 27, 1922	Do.
230559	♀	do	do	do	Nov. 22, 1922	Beardstown, Ill. (6 mi. NE.).
230560	♀	do	do	do	Dec. 5, 1922	Beardstown, Ill. (7½ mi. NE.).
230575	♀	do	do	Nov. 23, 1922	Nov. 27, 1922	Beardstown, Ill. (9 mi. N.).
†230581	♀	do	do	do	Dec. 3, 1922	Browning, Ill.
230582	♀	do	do	do	Nov. 30, 1922	Beardstown, Ill.
230584	♀	do	do	do	Dec. 7, 1922	Bath, Ill. (4 mi. S.).
230586	♀	do	do	do	Dec. 30, 1922	Barnhill, Ill. (4 mi. W.).
230591	♂	do	do	do	Dec. 31, 1922	Beardstown, Ill. (7 mi. N.).
230601	♂	do	do	do	Jan. 26, 1923	Bath, Ill.
230604	♂	do	do	do	Dec. —, 1922	Hopkins County, Ky.
†230605	♂	do	do	do	Dec. 1, 1922	Browning, Ill.
230607	♂	do	do	do	Dec. 7, 1922	Crane Lake, Ill.
230622	♂	do	do	do	Dec. 15, 1922	Sheldons Grove, Ill.
230627	♀	do	do	do	Dec. 20, 1922	Mason County, Ill.
230629	♀	do	do	do	Nov. 23, 1922	Beardstown, Ill.
230643	♂	do	do	Nov. 24, 1922	Dec. 20, 1922	Do.
230647	♂	do	do	do	do	Big Lake, Ark.
230654	♂	do	do	do	Nov. 25, 1922	Beardstown, Ill.
230660	♂	do	do	do	Jan. 11, 1923	Big Lake, Ark.
230663	♂	do	do	do	Dec. 17, 1922	Bath, Ill.
230664	♂	do	do	do	Dec. 15, 1922	Smithland, Ky.
230668	♂	do	do	do	Dec. 1, 1922	Beardstown, Ill.
230670	♀	do	do	do	Dec. 14, 1922	Bath, Ill.
230678	♀	do	do	do	Dec. 16, 1922	Chandlerville, Ill.
†230683	♂	do	do	do	Nov. 28, 1922	Browning, Ill.
†230684	♂	do	do	do	do	Do.
230692	♂	do	do	do	Dec. 27, 1922	Shawneetown, Ill.
230693	♂	do	do	do	Jan. 18, 1923	Big Lake, Ark.
230695	♂	do	do	do	Dec. 19, 1922	Mason County, Ill.

² Date approximate.

Mallard—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
230696	♂	F. C. Lincoln	Browning, Ill.	Nov. 24, 1922	Dec. 6, 1922	De Witt, Ark.
230697	♀	do	do	do	Dec. 13, 1922	Beardstown, Ill.
230699	♀	do	do	do	Nov. 18, 1922 ³	Browning, Ill.
230703	♀	do	do	do	Dec. 17, 1922	Bath, Ill.
230731	♂	do	do	do	Nov. 30, 1922	Beardstown, Ill. (5 mi. NE.).
230733	♂	do	do	do	Nov. 28, 1922	Beardstown, Ill. (2 mi. N.).
230735	♂	do	do	do	Dec. 4, 1922	Rush Tower, Mo.
†230740	♂	do	do	do	Dec. 2, 1922	Browning, Ill.
230743	♂	do	do	do	Dec. 27, 1922	Beardstown, Ill.
230749	♂	do	do	do	Nov. 27, 1922	Bath, Ill.
230760	♀	do	do	do	Dec. 14, 1922	Bath, Ill. (2 mi. S.).
230765	♀	do	do	do	Dec. 10, 1922	Snicarte, Ill.
230766	♀	do	do	do	Jan. 11, 1923	Union County, Ark.
230770	♂	do	do	Nov. 25, 1922	Dec. 27, 1922	Beardstown, Ill. (7 mi. N.).
230771	♂	do	do	do	Dec. 7, 1922	Bath, Ill. (3 mi. SW.).
230772	♂	do	do	do	Jan. 11, 1923	Marvell, Ark. (25 mi. S.).
†230773	♂	do	do	do	Dec. 2, 1922	Browning, Ill.
†230776	♂	do	do	do	Dec. 9, 1922	Do.
†230780	♀	do	do	do	Nov. 25, 1922	Do.
230787	♂	do	do	do	Dec. 8, 1922	Havana, Ill. (12 mi. N.).
†230793	♂	do	do	do	Nov. 26, 1922	Browning, Ill.
†230799	♂	do	do	do	Nov. 25, 1922	Do.
†230806	♀	do	do	do	Dec. 2, 1922	Do.
†230809	♀	do	do	do	Nov. 25, 1922	Do.
230814	♂	do	do	do	Dec. 19, 1922	Eunice, La.
230817	♂	do	do	do	Dec. 13, 1922	Havana, Ill.
†230819	♂	do	do	do	Dec. 1, 1922	Browning, Ill.
230821	♂	do	do	do	Latter part of season, 1922	Mount Vernon, Ind.
230822	♂	do	do	do	Dec. 23, 1922	Peoria, Ill.
†230827	♀	do	do	do	Nov. 30, 1922	Browning, Ill.
†230829	♀	do	do	do	Nov. 30, 1922 ²	Do.
†230839	♂	do	do	Nov. 26, 1922	Nov. 26, 1922	Do.
230842	♂	do	do	do	Jan. —, 1923	Meredosia, Ill.
230847	♀	do	do	do	Dec. 2, 1922	Beardstown, Ill. (6 mi. S.).
230852	♂	do	do	do	Nov. 30, 1922	Beardstown, Ill. (9 mi. NE.).
†230856	♂	do	do	do	do	Browning, Ill.
230860	♂	do	do	do	Dec. 15, 1922	Mason County, Ill.
230862	♂	do	do	do	Dec. 19, 1922	Havana, Ill. (6 mi. S.).
230867	♂	do	do	do	Dec. 27, 1922	Sikeston, Mo.
230868	♂	do	do	do	do	McCrory, Ark.
230870	♂	do	do	do	Dec. 11, 1922	Beardstown, Ill. (7 mi. N.).
230872	♂	do	do	do	Nov. 30, 1922	Crane Lake, Ill. (2 mi. E.).
230886	♂	do	do	do	do	Beardstown, Ill.
230891	♀	do	do	do	Jan. 9, 1923	Reelfoot Lake, Tenn.
230893	♀	do	do	do	Nov. 29, 1922	Bluff City, Ill.
230896	♀	do	do	do	Dec. 14, 1922	Snicarte, Ill.
230897	♀	do	do	do	Jan. 23, 1923	Peach Orchard, Ark.
230898	♀	do	do	do	Dec. 13, 1922	Cardwell, Mo. (4 mi. SW.).
230899	♀	do	do	do	Dec. 9, 1922	Beardstown, Ill. (5 mi. NE.).

² Date approximate.³ An obvious error; return reported after the close of the hunting season; bird possibly killed illegally.

Mallard—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
230901	♀	F. C. Lincoln	Browning, Ill.	Nov. 26, 1922	Dec. 1, 1922	Beardstown, Ill.
230913	♀	do	do	do	Dec. 8, 1922	Do.
230915	♀	do	do	do	Dec. 15, 1922	Mason County, Ill.
†230918	♀	do	do	do	Dec. 6, 1922	Browning, Ill.
230927	♀	do	do	do	Jan. 27, 1923	Bogota, Tenn. (2 mi. E.).
230929	♂	do	do	do	Nov. 28, 1922	Chandlerville, Ill. (8 mi. W.).
†230930	♂	do	do	do	Nov. 30, 1922	Browning, Ill.
230931	♂	do	do	do	Dec. 19, 1922	Havana, Ill. (12 mi. S.).
230932	♂	do	do	do	Dec. 4, 1922	Bath, Ill. (8 mi. SW.).
230939	♀	do	do	do	Dec. 17, 1922	Bath, Ill. (4 mi. S.).
230952	♀	do	do	Nov. 27, 1922	Dec. 27, 1922	Bath, Ill. (12½ mi. S.).
230955	♀	do	do	do	Dec. 9, 1922	Reelfoot Lake, Tenn.
230962	♀	do	do	do	Dec. 14, 1922	Snicarte, Ill.
230964	♀	do	do	do	Dec. 26, 1922	Havana, Ill.
230970	♀	do	do	do	Dec. 1, 1922	Frederick, Ill. (4 mi. N.).
230972	♂	do	do	do	Nov. 30, 1922	Sangamon River, Ill.
230984	♂	do	do	do	Dec. 28, 1922	Seymour, Ill.
†230991	♂	do	do	Nov. 28, 1922	Nov. 29, 1922	Browning, Ill.
231004	♂	do	do	do	Dec. 7, 1922	Naples, Ill. (2 mi. S.).
†231009	♂	do	do	do	Dec. 25, 1922	Browning, Ill.
231011	♂	do	do	do	Dec. 13, 1922	Beardstown, Ill.
231016	♂	do	do	do	Nov. 30, 1922	Frederick, Ill.
231030	♀	do	do	do	May 12, 1923	Burnt Wood Lake, Saskatchewan.
†231033	♀	do	do	do	Nov. 28, 1922	Browning, Ill.
†231039	♀	do	do	do	do	Do.
231043	♂	do	do	do	Dec. 20, 1922	Bluff City, Ill.
231056	♂	do	do	do	Dec. 10, 1922	Crane Lake, Ill.
231059	♂	do	do	do	Dec. 7, 1922	Bath, Ill.
231062	♂	do	do	do	May 3, 1923 ¹	Oxford House, Manitoba.
231068	♀	do	do	do	Dec. 30, 1922	Bath, Ill. (4 mi. S.).
231078	♂	do	do	do	Dec. 7, 1922	Beardstown, Ill.
231108	♂	do	do	Nov. 30, 1922	Dec. 9, 1922	Beardstown, Ill. (10 mi. NE.).
231115	♀	do	do	do	Dec. 25, 1922	Snicarte, Ill.
231121	♀	do	do	do	Jan. 10, 1923	Cash, Ark. (6½ mi. S.).
231124	♀	do	do	do	Dec. 19, 1922	Beardstown, Ill. (6 mi. NE.).
231127	♀	do	do	do	Dec. 27, 1922	Astoria, Ill.
231132	♂	do	do	Dec. 2, 1922	Dec. 16, 1922	Beardstown, Ill.
231141	♂	do	do	do	Dec. 26, 1922	Havana, Ill. (5 mi. NE.).
†231145	♂	do	do	do	Dec. 18, 1922	Browning, Ill.
231150	♂	do	do	do	Jan. 20, 1923	Lauderdale County, Ala.
231158	♂	do	do	do	Dec. 16, 1922	Beardstown, Ill.
231164	♀	do	do	do	Dec. 22, 1922	Crane Lake, Ill.
†231181	♀	do	do	do	Dec. 11, 1922	Browning, Ill. 1½ mi. SE.).
231198	♂	do	do	Dec. 3, 1922	Dec. 30, 1922	Frederick, Ill.
231202	♂	do	do	do	do	Beardstown, Ill. (7 mi. N.).
231217	♀	do	do	do	Dec. 29, 1922	Bath, Ill. (9 mi. S.).
†231227	♂	do	do	Dec. 4, 1922	do	Browning, Ill. (1½ mi. S.).
231240	♂	do	do	do	Jan. 8, 1923	Bradley County, Ark.
231253	♀	do	do	do	Dec. —, 1922	Crane Lake, Ill.
231262	♀	do	do	do	Dec. 13, 1922	Beardstown, Ill.
231265	♀	do	do	do	Dec. 20, 1922	Cass County, Ill.
231267	♀	do	do	do	Dec. 25, 1922	Bath, Ill.
231272	♀	do	do	do	Jan. 4, 1923	Bellville, Tex.

¹ Date approximate.

Mallard—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
231273	♀	F. C. Lincoln	Browning, Ill.	Dec. 4, 1922	Dec. 25, 1922	Snicarte, Ill. ($\frac{1}{2}$ mi. N.).
231278	♂	do.	do.	Dec. 5, 1922	Dec. 12, 1922	Crane Lake, Ill.
231281	♂	do.	do.	do.	Dec. 10, 1922	Snicarte, Ill.
231283	♂	do.	do.	do.	Jan. 27, 1923	Tilton, Ark.
†231288	♂	do.	do.	do.	Nov. —, 1922 ³	Crane Lake, Ill.
231304	♀	do.	do.	do.	Dec. 25, 1922	12 miles from Brinkley, Ark. (Cache R.).
231306	♀	do.	do.	do.	Dec. 30, 1922	Maunie, Ill.
231309	♀	do.	do.	do.	Dec. 8, 1922	Beardstown, Ill. (3 mi. NE.).
231310	♀	do.	do.	do.	Dec. 13, 1922	Snicarte, Ill.
231314	♂	do.	do.	Dec. 6, 1922	Dec. 15, 1922	White River, Ark.
231315	♂	do.	do.	do.	Dec. 17, 1922	Schuyler County, Ill.
231321	♂	do.	do.	do.	Dec. 13, 1922	Snicarte, Ill.
231323	♂	do.	do.	do.	Dec. 14, 1922	Crittenden County, Ark.
231325	♀	do.	do.	do.	Dec. 28, 1922	Meredosia, Ill.
231326	♀	do.	do.	do.	Dec. 20, 1922	Bath, Ill.
101682	♂	E. A. McIlhenny.	Avery Id., La.	Feb. 9, 1922	Aug. 17, 1922	Cumberland Lake, Saskatchewan.
101684	♂	do.	do.	Feb. 15, 1922	Dec. 16, 1922	New Harmony, Ind.
101690	♂	do.	do.	Feb. 9, 1922	Nov. 21, 1922	Avery Id., La.
101695	♂	do.	do.	do.	Jan. 9, 1923	Do.
203305	♀	John Broecker ⁴	Portage des Sioux, Mo.	Jan. 22, 1923	Apr. 29, 1923	The Pas, Manitoba (60 mi. E.).
203332	♂	do.	do.	Jan. 24, 1923	May 1, 1923	The Pas, Manitoba (8 mi. E.).
†203348	♀	do.	do.	Jan. 27, 1923	Mar. 6, 1923	Portage des Sioux, Mo.
203365	do.	do.	do.	Jan. 31, 1923	Jan. 29, 1923	Lonoke County, Ark.
203385	♂	do.	do.	do.	May 1, 1923	Peace R., Alberta. ⁵
†203409	♀	do.	do.	Feb. 3, 1923	Mar. 6, 1923	Portage des Sioux, Mo.
203420	♂	do.	do.	do.	Feb. 18, 1923	Gale, Ill.
203548	♀	do.	do.	Mar. 4, 1923	May 10, 1923	Reindeer R., Saskatchewan.
203683	♀	do.	do.	Mar. 24, 1923	May 16, 1923	Fish R., Saskatchewan.
101302		L. V. Walton ⁴	Cuivre Id., Mo.	Jan. 7, 1922	Dec. 22, 1922	Holcomb, Miss.
101305		do.	do.	Jan. 8, 1922	Nov. 16, 1922	Devine, Ill.
101313		do.	do.	Jan. 7, 1922	Nov. 24, 1922	Bureau, Ill. (3 mi. S.).
101319		do.	do.	Jan. 11, 1922	Dec. 6, 1922	Old Monroe, Mo.
101320	♀	do.	do.	Nov. 21, 1921	Dec. 18, 1921	Treadway Lake, Ill.
101327		do.	do.	Jan. 7, 1922	Oct. 12, 1922 ²	Prince Albert, Saskatchewan (15 mi. NW.).
101328		do.	do.	Jan. 3, 1922	Jan. 27, 1922	Russell, Ark.
101329		do.	do.	Jan. 8, 1922	Dec. 26, 1922	Beaumont, Tex. (5 mi. S. W.).
101355		do.	do.	Jan. 7, 1922	Jan. 18, 1923	Van Buren, Ark. (5 mi. E.).
101365		do.	do.	Jan. 11, 1922	Sept. 30, 1922	Portage la Prairie, Manitoba (13 mi. N.).
101374		do.	do.	Jan. 8, 1922	Dec. 7, 1922	Clarendon, Ark. ² (7 mi. S.).
101376		do.	do.	Jan. 7, 1922	Nov. 12, 1922	Lake Williams, N. Dak.
101377		do.	do.	Jan. 8, 1922	Feb. 8, 1922	Morse Mill, Mo.
101388		do.	do.	Jan. 12, 1922	Sept. 16, 1922	Jamesville, S. Dak.
101391		do.	do.	Jan. 8, 1922	Nov. 27, 1922	Chesterfield, Mo.
101395		do.	do.	Jan. 7, 1922	Oct. 15, 1922	Ellendale, N. Dak.
101399		do.	do.	Jan. 8, 1922	Jan. 24, 1922	East St. Louis, Mo.

² Date approximate.³ An obvious error; return reported after the close of the hunting season; bird possibly killed illegally.⁴ Under direction of Joseph Pulitzer, of St. Louis, Mo.⁵ Between Forts Vermilion and Chipewyan.

Mallard—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
101962	---	L. V. Walton	Cuivre Id., Mo.	Jan. 15, 1923	Jan. 31, 1923	Reelfoot Lake, Tenn.
101997	---	do	do	do	May 3, 1923	Isle-a-la-Crosse, Saskatchewan (25 mi. NE.),
102006	♂	do	do	Jan. 19, 1922	Dec. 30, 1922	Meredosia, Ill.
102023	♂	do	do	do	Dec. 28, 1922	Apex, Mo.
102028	♀	do	do	Jan. 22, 1922	Dec. 6, 1922	Middletown, Iowa.
102036	---	do	do	Jan. 30, 1922	Nov. 17, 1922	Salt River, Ralls County, Mo.
102039	♂	do	do	do	Nov. 24, 1922 ¹	Appleton, Minn.
102040	---	do	do	do	Jan. 13, 1923	Pulaski, Tenn.
102047	♂	do	do	do	Nov. 8, 1922	Mouth of Missouri River (1 mi. S.).
102049	♂	do	do	do	Nov. 24, 1922	Rock County, Wis.
102050	♂	do	do	do	Dec. 9, 1922	Grafton, Ill. (3 mi. N.).
102057	♀	do	do	do	Apr. 19, 1923	Wordsworth, Saskatchewan.
102067	♀	do	do	do	Dec. 13, 1922	Arkansas River (E. part Okla.).
102070	♂	do	do	Feb. 1, 1922	Dec. 20, 1922	St. Charles, Ark.
102072	♀	do	do	Feb. 12, 1922	Nov. 19, 1922	Coahoma County, Miss.
102075	♂	do	do	Feb. 16, 1922	Dec. 10, 1922	Webb City, Mo. (16 mi. NW.).
102087	♀	do	do	Feb. 21, 1922	Latter part of season, 1922.	Mount Vernon, Ind.
200103	♂	do	do	Feb. 22, 1922	Dec. 23, 1922	Sheldons Grove, Ill.
200105	♂	do	do	do	Dec. 29, 1922	Elk City, Okla. (15 mi. S.).
200110	♀	do	do	do	Nov. 28, 1922	Wagner, Okla.
200112	♂	do	do	Mar. 1, 1922	Nov. 18, 1922 ¹	Alta Loma, Tex.
200119	♀	do	do	Mar. 4, 1922	Oct. 16, 1922	N. pt. Clearwater County, Minn.
200122	♂	do	do	do	Nov. 5, 1922	Herman, Minn. (3½ mi. SE.).
200123	♀	do	do	do	Dec. 14, 1922	Crowley, La. (18 mi. N.)
200124	♂	do	do	do	Feb. 3, 1923	Portage des Sioux, Mo. ⁶
200136	♂	do	do	Jan. 6, 1923	Feb. 13, 1923	Do. ⁶
200142	♀	do	do	Jan. 7, 1923	do	Do. ⁶
200142	♀	do	do	do	Mar. 24, 1923 ²	Malden, Mo.
200179	♀	do	do	do	Feb. 24, 1923 ³	Jacob, Ill.
200208	---	do	do	Jan. 8, 1923	May 19, 1923	Saint Brieux, Saskatchewan (8 mi. W.).
200263	---	do	do	Jan. 10, 1923	Feb. 25, 1923	East Cairo, Ky.
200339	---	do	do	do	Aug. 3, 1923	Lake la Plonge, Saskatchewan.
200355	---	do	do	Jan. 11, 1923	July 4, 1923 ²	Cross Lake Post, Manitoba.
200373	---	do	do	do	Jan. 18, 1923	Finley, Tenn.
200395	---	do	do	do	Mar. 16, 1923	Momence, Ill. (5 mi. E.).
200417	---	do	do	Jan. 12, 1923	May 1, 1923 ²	Sled Lake, Green Lake, Saskatchewan (20 mi. NE.).
200586	---	do	do	Jan. 17, 1923	Feb. 10, 1923	Delaplaine, Ark.
200590	---	do	do	do	Mar. 3, 1923	Claryville, Mo.
205251	♀	do	do	Feb. 2, 1923	Feb. 13, 1923	Portage des Sioux, Mo. ⁶
205321	♀	do	do	Feb. 8, 1923	June 5, 1923 ²	Lake Winnipegosis, Manitoba.

¹ Date approximate.

⁶ Trapped by John Broeker and again released.

Mallard—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
205330	♂	L. V. Walton	Cuivre Id., Mo.	Feb. 9, 1923	Mar. 17, 1923	Lillbourn, Mo.
205342	♂	do	do	do	Feb. 13, 1923	Portage des Sioux, Mo. ⁶
205522	♂	do	do	Mar. 1, 1923	Mar. 25, 1923	Cuba, Mo.
205553	♀	do	do	Mar. 2, 1923	"Spring, 1923"	Duck Lake, Saskatchewan.
205590	♂	do	do	Mar. 4, 1923	Mar. 24, 1923	Crane Lake, Ill.
205592	♀	do	do	do	May 21, 1923	Rocklake, N. Dak.
205787	♂	do	do	Mar. 17, 1923	Apr. 9, 1923	Peruque, Mo.
205808	♂	do	do	Mar. 19, 1923	May 4, 1923	Summerberry River, Saskatchewan.
205840	♀	do	do	Mar. 20, 1923	Apr. 19, 1923	Pinehurst Lake, Alberta.
*36837	♀	A. A. Allen	Ithaca, N. Y.	Mar. 18, 1918	Sept. 6, 1920	Quill Lake, Saskatchewan.
*36839	♂	do	do	Apr. 18, 1918	Fall, 1919	Near Chamberlain, S. Dak.
*36840	♂	do	do	Mar. 18, 1918	Nov. 11, 1920	Grand Chenier, La.
*36845	♂	do	do	Apr. 8, 1918	Nov. 19, 1921	Lockport, La.
*36858	♀	do	do	Mar. 18, 1918	Sept. 25, 1920	Ferguson Flats, Alberta.
†*37425	♂	H. S. Osler	Lake Scugog, Ontario.	Sept. 25, 1922	Oct. 16, 1922	Lake Scugog, Ontario.
4616	do	do	do	Sept. 27, 1920	Dec. 4, 1920	Quitman County, Miss.
4640	♂	do	do	Sept. 30, 1920	Nov. 27, 1920	Wrightville Beach, N. C.
4697	do	do	do	Oct. 23, 1920	Nov. 7, 1920	Ceasarea, Ontario.
4698	do	do	do	do	Nov. 18, 1920	Do.
5101	do	do	do	Nov. 6, 1920	Dec. 6, 1920	Long Point Bay, Lake Erie, Ontario.
5103	do	do	do	do	Jan. 15, 1921	St. Andrews, Fla.
5104	do	do	do	do	Nov. 15, 1920	Port Rowan, Ontario.
5158	do	do	do	Sept. 12, 1921	Nov. 11, 1922	Toledo, Ohio (2½ mi. E.).
5159	do	do	do	do	Oct. 4, 1921	Durham County, Ontario.
101180	do	do	do	Aug. 22, 1922	Sept. 2, 1922	Orillia, Ontario.
†101258	do	do	do	Aug. 29, 1922	Oct. 10, 1922	Lake Scugog, Ontario.
101259	do	do	do	do	Oct. 19, 1922	Ottawa County, Ohio.
228442	♀	do	do	Oct. 7, 1922	Nov. 9, 1922	Fort Valley, Ga. (6 mi. N.).
228624	do	do	do	Oct. 21, 1922	Feb. 10, 1923	Blaney, S. C.
202420	im	H. L. Felt ⁷	Findlater, Saskatchewan.	Sept. 3, 1922	Nov. 25, 1922	Catara, La. (3 mi. N.).

Mallard × Black Duck: *Anas platyrhynchos* × *A. rubripes*

102588	♂	F. C. Lincoln	Browning, Ill.	Mar. 10, 1922	Dec. 17, 1922	Cove, Tex.
5118	do	H. S. Osler	Lake Scugog, Ontario.	Aug. 27, 1921	Oct. 20, 1921	Niagara-on-the-Lake, Ontario.

⁶ Trapped by John Broeker and again released.⁷ Under direction of Fred Bradshaw, of Regina, Saskatchewan.

Black Duck: *Anas rubripes*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
102907	---	H. K. Job.	Amston, Conn.	Oct. 11, 1922	Jan. 1, 1923	Matthews County, Va.
102916	---	do.	do.	Oct. 14, 1922	Dec. 7, 1922	Essex, Conn.
102921	---	do.	do.	Oct. 12, 1922	Dec. 31, 1922	Riverhead, N. Y.
102938	---	do.	do.	Oct. 10, 1922	Jan. 30, 1923 ³	Peletier, N. C.
102953	---	do.	do.	Oct. 19, 1922	Jan. 15, 1923	Hog Island Bay, Va.
102966	---	do.	do.	do.	Dec. 15, 1922	Do.
102984	♀	do.	do.	Nov. 13, 1922	Nov. 22, 1922	Flanders, Long Island, N. Y.
102990	---	do.	do.	Oct. 14, 1922	Dec. 19, 1922	Back Bay, Va.
102445	♂	F. C. Lincoln.	Browning, Ill.	Mar. 7, 1922	Dec. 25, 1922 ³	Beardstown, Ill.
102450	♀	do.	do.	do.	Nov. 27, 1922	La Salle, Ill.
102850	♀	do.	do.	Mar. 14, 1922	Dec. 25, 1923	Sheldons Grove, Ill.
230234	♂	do.	do.	Nov. 19, 1922	Nov. 20, 1922	Beardstown, Ill. (7 mi. N.).
230236	♂	do.	do.	do.	Dec. —, 1922	Beardstown, Ill.
230338	♀	do.	do.	Nov. 20, 1922	Dec. 9, 1922	Crane Lake, Ill.
230486	♀	do.	do.	Nov. 22, 1922	Nov. 28, 1922	Do.
†230487	♀	do.	do.	do.	Nov. 27, 1922	Browning, Ill.
230598	♀	do.	do.	do.	Jan. 25, 1923	Fisher, Ark. (7 mi. E.).
230907	♀	do.	do.	Nov. 26, 1922	Nov. 29, 1922	Beardstown, Ill. (7 mi. NE.).
230912	♂	do.	do.	do.	Dec. 27, 1922	Bath, Ill.
†231087	♂	do.	do.	Nov. 28, 1922	Dec. 12, 1922	Browning, Ill.
231220	♂	do.	do.	Dec. 3, 1922	Nov. —, 1922 ³	Crane Lake, Ill.
231249	♂	do.	do.	Dec. 4, 1922	Dec. 10, 1922	Sheldons Grove, Ill.
100851	♂	Frank Thompson. ⁴	Bar Harbor, Me.	Oct. 17, 1921	Jan. 3, 1922	Cape May, N. J.
100852	♂	do.	do.	do.	Nov. 1, 1921	Franklin, Me.
100854	♂	do.	do.	do.	Jan. 7, 1922	Moriches, Long Island, N. Y.
100862	♂	do.	do.	Oct. 21, 1921	Oct. 24, 1921 ³	Franklin, Me.
100867	♀	do.	do.	Oct. 17, 1921	Nov. 15, 1921	Franklin Bay, Me.
100868	♀	Joseph Pulitzer.	Lake Naraguagus, near Franklin, Me.	Sept. 26, 1921	Jan. 31, 1922	Cape May, N. J.
100870	---	Frank Thompson. ⁴	Bar Harbor, Me.	Oct. 17, 1921	Oct. 22, 1921	Franklin, Me.
100876	♀	do.	do.	do.	Oct. 29, 1921	Do.
100882	♀	do.	do.	do.	Dec. 14, 1921	Ellsworth, Me.
100891	♀	Joseph Pulitzer.	Lake Naraguagus, near Franklin, Me.	Sept. 30, 1921	Oct. 8, 1921	Franklin, Me.
†100895	♂	do.	do.	Sept. 26, 1921	Sept. 27, 1921	Lake Naraguagus, near Franklin, Me.
100896	♀	do.	do.	do.	Jan. 5, 1922	Silva, Va.
100897	♀	Frank Thompson. ⁴	Bar Harbor, Me.	Oct. 17, 1921	Dec. 2, 1921	Skillings River, Me.
100898	♂	Joseph Pulitzer.	Lake Naraguagus, near Franklin, Me.	Sept. 26, 1921	Oct. —, 1921	Hancock County, Me.
†101075	---	Frank Thompson. ⁴	do.	Sept. 24, 1922	Oct. 16, 1922	Franklin, Me.
101078	♀	do.	Bar Harbor, Me.	Oct. 21, 1921	Jan. 30, 1922	Chester River, Md. (mouth).

² Date approximate.

³ An obvious error; reported after the close of the hunting season; bird possibly killed illegally.

⁴ Under direction of Joseph Pulitzer, of St. Louis, Mo.

Black Duck—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
101088	♀	Joseph Pulitzer.	Spring Run Pond, Hancock County, Me.	Oct. 10, 1922	Oct. 16, 1922	Franklin, Me.
228007	-----	do	do	Oct. 31, 1922	Dec. 14, 1922	Harrington, Me.
228009	-----	do	do	do	Nov. 1, 1922	Eastbrook, Me.
228014	-----	do	do	do	Nov. 6, 1922	Tunk Pond, Me.
228016	-----	do	do	do	Nov. 3, 1922	Eastbrook, Me.
228017	-----	do	do	do	Jan. 16, 1923	Chincoteague, Va. (1 mi. N.).
228021	-----	do	do	do	Nov. 6, 1922	Tunk Pond, Me.
228033	-----	do	do	do	do	Do.
228042	-----	do	do	Nov. 6, 1922	do	Do.
228046	-----	do	do	Oct. 31, 1922	do	Do.
228052	-----	do	do	Oct. 17, 1922	Nov. 15, 1922	Webbs Pond, Me.
228060	-----	do	do	Oct. 20, 1922	Nov. 6, 1922	Tunk Pond, Me.
228078	-----	do	do	Oct. 15, 1922	do	Do.
228083	-----	do	do	Oct. 18, 1922	Nov. 10, 1922	Do.
228089	♂	do	do	Oct. 20, 1922	Nov. 28, 1922	Gouldsboro, Me.
228092	♂	do	do	do	Oct. 28, 1922	Eastbrook, Me.
228098	-----	do	do	do	Nov. 28, 1922	Gouldsboro, Me.
228101	-----	do	do	do	Dec. 28, 1922	Eastern Shore of Va. (opp. Eastville Station).
228111	-----	do	do	do	Jan. 30, 1923	Great Bay, Island Beach, N. J.
228113	-----	do	do	do	Nov. 7, 1922	Tunk Pond, Me.
228114	-----	do	do	do	Nov. 18, 1922	Ocean City, Md. (1½ mi. NW.).
228115	♀	do	do	do	Nov. 8, 1922	Barnegat City, N. J.
228116	-----	do	do	do	Oct. 16, 1922	Franklin, Me.
228120	-----	do	do	do	Nov. 4, 1922	Tunk Pond, Me.
228126	♂	do	do	do	Dec. 26, 1922	Sorrento, Me.
228132	♀	do	do	do	Oct. 27, 1922	Eastbrook, Me.
228138	-----	do	do	Oct. 24, 1922	Nov. 7, 1922	Tunk Pond, Me.
228147	♀	do	do	Oct. 20, 1922	Dec. 5, 1922	East Brewster, Me.
228152	-----	do	do	Oct. 30, 1922	Nov. 3, 1922	Eastbrook, Me.
228166	-----	do	do	do	Nov. 1, 1922	North Hancock, Me.
228167	-----	do	do	Oct. 31, 1922	Dec. 14, 1922	Metompkin Bay, Eastern Shore, Va.
228172	-----	do	do	Oct. 27, 1922	Nov. 11, 1922	Tunk Pond, Me.
228177	-----	do	do	do	Nov. 7, 1922	Do.
228180	-----	do	do	Oct. 28, 1922	Nov. 6, 1922	Do.
228185	-----	do	do	Oct. 27, 1922	Nov. 1, 1922	Eastbrook, Me.
228196	-----	do	do	Oct. 30, 1922	Nov. 10, 1922	Tunk Pond, Me.
101393	-----	L. V. Walton ⁴	Cuivre Island, Mo.	Jan. 11, 1922	Dec. —, 1922	Beardstown, Ill.
102035	-----	do	do	Jan. 30, 1922	Dec. 10, 1922	Batchtown, Ill.
200284	-----	do	do	Jan. 10, 1923	May 4, 1923	Post, on Ogoki River, Ontario.
101811	♂	A. A. Allen	Ithaca, N. Y.	Jan. 19, 1923	Apr. 28, 1923	Parry Sound, Georgian Bay, Ontario (16 mi. E.).
10505	juv.	R. W. Tufts	Seal Island, Nova Scotia.	June 8, 1922	Nov. 8, 1922	Yarmouth County, Nova Scotia.
†10509	juv.	do	do	do	Aug. 26, 1922	Seal Island, Nova Scotia.
*36903	-----	H. S. Osler	Lake Scugog, Ontario.	Aug. 31, 1918	Mar. 31, 1921	Curve Lake, Ontario.
*36920	-----	do	do	Oct. 15, 1918	Apr. 26, 1920	Ellis Bay, Quebec.

⁴ Under direction of Joseph Pulitzer, of St. Louis, Mo.

Black Duck—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
*36974	-----	H. S. Osler	Lake Scugog, Ontario.	Sept. 9, 1919	Sept. 15, 1920	Peterborough, Ontario.
*36986	-----	do	do	Sept. 10, 1918	Dec. 22, 1920	Townsend, Va.
*37326	-----	do	do	Oct. 1, 1921	Jan. 30, 1923	Lake Providence, La.
*37330	-----	do	do	do	Oct. 17, 1921	Brechin, Ontario.
†*37338	-----	do	do	Oct. 3, 1921	Nov. 2, 1921	Lake Scugog, Ontario.
*37340	-----	do	do	do	Oct. 22, 1921	Kent County, Del.
*37341	♂	do	do	do	Nov. 23, 1921	Toledo, Ohio.
*37342	-----	do	do	do	Nov. 17, 1921	Pontiac, Mich.
*37348	-----	do	do	do	Nov. 13, 1921	East St. Louis, Ill.
*37350	-----	do	do	do	Feb. 20, 1922	Cartersville, Ga.
*37362	-----	do	do	Oct. 5, 1921	Jan. 17, 1922	Havre de Grace, Md.
*37367	-----	do	do	do	Oct. 13, 1921	Big Rice Bay, Ontario.
*37368	-----	do	do	Oct. 8, 1921	Nov. 3, 1921	Port Clinton, Ohio.
*37369	-----	do	do	Oct. 3, 1921	Winter, 1922	North Louisiana.
*37385	-----	do	do	Oct. 12, 1921	Oct. —, 1921	Port Rowan, Ontario.
*37406	-----	do	do	Sept. 24, 1922	Dec. 10, 1922	South Santee River, S. C.
*37410	-----	do	do	do	Jan. 22, 1923	Chicamuxen Creek, Charles County, Md.
*37433	-----	do	do	Sept. 25, 1922	Nov. 10, 1922	Hog Island, Va.
*37440	-----	do	do	do	Nov. 30, 1922	Havana, Ill.
*37443	-----	do	do	do	Nov. 3, 1922	Onancock, Va. (7 mi. N. W.).
*37455	-----	do	do	do	Dec. 27, 1922	S. E. corner of Mississippi, 2 mi. from Alabama State line.
*37465	-----	do	do	Sept. 26, 1922	Jan. 16, 1923	Tuscaloosa County, Ala.
*37469	-----	do	do	do	Feb. 4, 1923 ²	Deals Island, Somerset County, Md.
*37470	-----	do	do	do	Dec. 1, 1922 ²	Clermont County, Ohio.
†*37474	-----	do	do	do	Oct. 27, 1922	Lake Scugog, Ontario.
*37475	-----	do	do	do	Jan. 22, 1923	Delaware River, Allowarp Creek, N. J.
*37478	-----	do	do	do	Oct. 23, 1922	Bay of Quinte, Ontario.
†*37482	-----	do	do	do	Oct. 15, 1922	Lake Scugog, Ontario.
*37486	-----	do	do	do	Dec. 20, 1922	Strathmere, N. J.
*37497	-----	do	do	Sept. 27, 1922	Nov. 11, 1922	Havre de Grace, Md. (15 mi. S.).
*37498	-----	do	do	do	Dec. 23, 1922	Speonk, Long Island, N. Y.
4503	-----	do	do	Sept. 3, 1920	Jan. 2, 1922	Near Saxis, Va.
4505	-----	do	do	do	Oct. 21, 1921	Hudson, S. Dak. (2 mi. S.).
†4506	-----	do	do	do	Sept. 3, 1920	Lake Scugog, Ontario.
4508	-----	do	do	do	Nov. 8, 1921	Peterboro, Ontario.
4518	-----	do	do	Sept. 9, 1920	Nov. 16, 1920	Port Clinton, Ohio.
4519	-----	do	do	do	Nov. 16, 1920	Normandale, Ontario.
4524	-----	do	do	Sept. 14, 1920	Dec. 7, 1920	Gueydon, La.
4525	-----	do	do	do	Nov. 2, 1920	Hay Bay, Ontario.
4526	-----	do	do	do	Oct. 25, 1921 ²	Sandbanks, Ontario. (?)
4542	-----	do	do	Sept. 15, 1920	Apr. 20, 1922	Lake Temiscaming, Quebec.
4543	-----	do	do	do	Jan. 1, 1921	Jamestown, Va.
4549	-----	do	do	do	Dec. 28, 1920	Owensboro, Ky.
4564	-----	do	do	Sept. 17, 1920	Fall, 1921	Lake Scugog, Ontario.
4568	-----	do	do	Sept. 18, 1920	Jan. 29, 1921	Bull's Island, S. C.
4570	-----	do	do	do	Jan. 13, 1921	Georgetown, S. C.

² Date approximate.

Black Duck—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
4573	----	H. S. Osler	Lake Scugog, Ontario.	Sept. 19, 1920	Nov. 9, 1921	Long Point, Lake Erie, Ontario.
4581	----	..do.	..do.	Sept. 24, 1920	Nov. 19, 1920	Melton, Indiana.
4587	----	..do.	..do.	..do.	Oct. 1, 1921	Orillia, Ontario.
4592	----	..do.	..do.	..do.	Nov. 29, 1920	Mouth of Econfinia River, Fla.
4596	----	..do.	..do.	Sept. 25, 1920	Dec. 17, 1921	Oakley, S. C.
4597	----	..do.	..do.	..do.	Nov. 26, 1920	Palestine, Tex.
4598	----	..do.	..do.	..do.	Feb. 5, 1921	Meltonville, Ala.
4602	----	..do.	..do.	..do.	Oct. 18, 1920	Cape Fear River, N. C.
4606	----	..do.	..do.	..do.	Fall, 1922	Pearl Beach, Mich.
4610	----	..do.	..do.	Sept. 26, 1920	Nov. 4, 1920	Caesarea, Ontario.
4611	----	..do.	..do.	..do.	Nov. 23, 1920	Summersville, Tenn.
4612	----	..do.	..do.	..do.	Nov. 19, 1920	Henderson, Ky.
4629	----	..do.	..do.	Sept. 27, 1920	Nov. 16, 1921	Tybee Island, S. C.
4630	----	..do.	..do.	Sept. 20, 1920	Nov. 20, 1920	Mouth of St. Clair River, Ontario.
4637	----	..do.	..do.	Sept. 29, 1920	Feb. 21, 1921 ²	Barnwell, S. C.
4645	----	..do.	..do.	Sept. 30, 1920	May —, 1921	Albany, Ontario.
4646	----	..do.	..do.	..do.	Nov. 23, 1921	Rock Hall, Md.
4650	----	..do.	..do.	Oct. 1, 1920	Nov. 11, 1921	Havre de Grace, Md.
4656	----	..do.	..do.	..do.	Oct. 23, 1920	Lake Scugog, Ontario.
4659	----	..do.	..do.	..do.	Dec. 16, 1922	Salem, N. J.
4664	----	..do.	..do.	Sept. 18, 1920	Nov. 7, 1921	Rock Hall, Md.
4668	----	..do.	..do.	Sept. 19, 1920	Nov. 12, 1920	Lake St. Clair Flats, Ontario.
4670	----	..do.	..do.	Sept. 18, 1920	Nov. 15, 1920	Rice Lake, Ontario.
4674	----	..do.	..do.	..do.	Oct. 30, 1920	Peterborough, Ontario (15 mi. N.).
4685	----	..do.	..do.	Oct. 4, 1920	Nov. 25, 1922 ²	Savannah, Ga.
4687	----	..do.	..do.	..do.	Nov. 1, 1921	San Souci Island, Georgian Bay, Ontario.
4688	♀	..do.	..do.	..do.	Nov. 23, 1920	Seyppel, Ark.
4734	----	..do.	..do.	Sept. 18, 1921	Dec. 25, 1922	Clarksville, Tenn.
4740	----	..do.	..do.	Sept. 19, 1921	Dec. 3, 1921	Crawfordsville, Ind.
4742	----	..do.	..do.	..do.	Oct. 12, 1921	Long Point, Ontario.
4745	----	..do.	..do.	..do.	Dec. 6, 1921	Long Point Bay, Ontario.
4747	----	..do.	..do.	..do.	Dec. 23, 1921	Williamsburg, Va. (13 mi. NW.).
4758	----	..do.	..do.	..do.	Nov. 14, 1921	Port Rowan, Ontario.
4761	----	..do.	..do.	..do.	Oct. 7, 1921	Port Perry, Ontario.
4765	----	..do.	..do.	..do.	Nov. 18, 1921	Lake Scugog, Ontario (5 mi. N.).
4769	----	..do.	..do.	..do.	Dec. 7, 1921	Port Rowan, Ontario.
4771	----	..do.	..do.	..do.	Dec. 2, 1921	New Castle, Del.
4773	----	..do.	..do.	..do.	Nov. 11, 1921	Woodford Co., Ill.
4780	----	..do.	..do.	Sept. 20, 1921	Jan. 2, 1922	Stony Brook Harbor, N. Y.
4783	----	..do.	..do.	..do.	Nov. 12, 1922	Pomeroy, Iowa.
4786	----	..do.	..do.	..do.	Nov. 8, 1921	Clear Creek, Ontario.
4787	----	..do.	..do.	..do.	Nov. 26, 1921	Toronto, Ontario (20 mi. E.).
4789	----	..do.	..do.	..do.	Nov. 10, 1921	Rockwood, Mich.
4796	----	..do.	..do.	..do.	Dec. 19, 1921	Rockford, Ohio (3 mi. E.).
4800	----	..do.	..do.	Sept. 23, 1921	Fall, 1921	Belleville, Ontario.
4804	----	..do.	..do.	Sept. 22, 1921	..do.	Lake Scugog, Ontario.
4810	----	..do.	..do.	..do.	..do.	Do.

² Date approximate.

Black Duck—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
4815	---	H. S. Osler	Lake Scugog, Ontario.	Sept. 25, 1921	Oct. 29, 1921	Lake Katchewanooka, Ontario.
4822	---	do	do	Sept. 26, 1921	Oct. 22, 1921	Hamilton, Ontario.
4884	---	do	do	Sept. 29, 1921	Nov. 12, 1921	Hardyville, Ky.
4888	---	do	do	do	Oct. 13, 1921	Marmora, Ontario.
4892	---	do	do	do	Nov. 10, 1921	Henry, Tenn.
4893	---	do	do	do	Dec. 11, 1922	Poplar Branch, N. C.
4895	---	do	do	do	Nov. 5, 1921	Mouth of Mississippi River, La.
5162	---	do	do	Sept. 12, 1921	Nov. 7, 1921	Penelon Falls, Ontario.
5169	---	do	do	Sept. 14, 1921	Nov. 2, 1921	Hay Bay, Lake Ontario, Ontario.
5181	---	do	do	do	Nov. 9, 1921	Cookstown, Ontario.
5195	---	do	do	Sept. 16, 1921	Nov. 6, 1922	Long Point, Lake Erie, Ontario.
5196	---	do	do	do	Dec. 4, 1921	Alexandria, La. (20 mi. NE.).
101102	---	do	do	Oct. 16, 1921	Jan. 3, 1922	Saxis, Va.
101124	---	do	do	Oct. 23, 1921	Nov. 2, 1922	St. Clair Flats, Ontario.
101131	---	do	do	Aug. 18, 1922	Nov. 18, 1922	Strawberry Island, Niagara River, N. Y.
101138	---	do	do	Aug. 20, 1922	do	Rockford, Mich. (3 mi. S.).
101140	---	do	do	do	Oct. 24, 1922	Woodville, N. Y.
101146	---	do	do	do	Oct. 13, 1922	Waubashene, Ontario.
101184	---	do	do	Aug. 23, 1922	Nov. 6, 1922	Saginaw, Mich.
101189	---	do	do	do	Oct. 23, 1922	Peterboro, Ontario (10 mi. NW.).
101191	---	do	do	Aug. 24, 1922	Oct. 29, 1922	Henry, Ill.
101196	---	do	do	do	Dec. 4, 1922	Taylor County, Fla.
101226	---	do	do	Aug. 26, 1922	Jan. 11, 1923	Accomac County, Va.
101233	---	do	do	Aug. 27, 1922	Dec. 3, 1922	Bayou Biloxi, La.
101245	---	do	do	Aug. 28, 1922	Dec. 19, 1922	Reelfoot Lake, Tenn.
101270	---	do	do	Aug. 31, 1922	Nov. 27, 1922	Port Clinton, Ohio.
101276	---	do	do	do	Oct. 26, 1922	Sandusky Marshes, Ohio.
101277	---	do	do	do	Nov. 15, 1922	Wachapreague, Va.
101280	---	do	do	do	Oct. 13, 1922	Fremont, Ohio.
101283	---	do	do	do	Dec. 14, 1922	Houma, La. (4 mi. SE.).
101284	---	do	do	do	Nov. 3, 1922	Port Penn, Del.
101293	---	do	do	Sept. 1, 1922	Dec. 23, 1922	Mouth of Bohemia River, Md.
101298	---	do	do	do	Dec. 1, 1922 ²	Kent County, Md.
101300	---	do	do	do	Dec. 5, 1922	Sweet Hall, Va.
202527	---	do	do	Nov. 24, 1922	Nov. 27, 1922	Salamanca, N. Y.
207504	---	do	do	Sept. 2, 1922	Nov. 9, 1922	Lake St. Clair, Ontario.
207505	---	do	do	do	Oct. 20, 1922	Pigeon Lake, Ontario.
207521	---	do	do	Sept. 4, 1922	Jan. 25, 1923	Kent Island, Md.
207529	---	do	do	Sept. 5, 1922	Jan. —, 1923	Wilmington, Del. (25 mi. S.).
207530	---	do	do	Sept. 6, 1922	Jan. 11, 1923	Kent Island, Md.
207531	---	do	do	do	Dec. 21, 1922	Curruck County, N. C.
207548	---	do	do	Sept. 10, 1922	Oct. 26, 1922	Lake Scugog, Ontario.
207623	---	do	do	Sept. 16, 1922	Nov. 14, 1922	Port Clinton, Ohio.
207634	---	do	do	Sept. 18, 1922	Nov. 21, 1922	Ashley County, Ark.
207635	---	do	do	do	Oct. 10, 1922	Coldwater, Ontario.
207644	---	do	do	Sept. 19, 1922	Nov. 17, 1922	Dunn, N. C.
207665	---	do	do	do	Dec. 6, 1922	Sandusky County, Ohio.
207666	---	do	do	do	Jan. 23, 1923	Franklin City, Va.
207667	---	do	do	do	Jan. 18, 1923	Chincoteague, Va.

² Date approximate.

Black Duck—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
207738	-----	H. S. Osler	Lake Seugog,	Sept. 21, 1922	Oct. 18, 1922	Green Creek, N. J.
†207741	-----	do	Ontario.	do	Oct. 10, 1922	Lake Seugog, Ontario
207745	-----	do	do	do	Oct. 29, 1922	Pindell, Md.
207747	-----	do	do	do	Oct. 19, 1922	Hay Bay, Ontario.
207755	-----	do	do	Sept. 22, 1922	Dec. 21, 1922	Dorchester County, Md.
207762	-----	do	do	do	Nov. 23, 1922	Bayou Meto, Ark.
207766	-----	do	do	do	Nov. 19, 1922	Henry, Ill.
207767	-----	do	do	do	Dec. 15, 1922	Cedar Island Beach, Va.
207772	-----	do	do	do	Nov. 24, 1922	Port Rowan, Ontario
207781	-----	do	do	do	Nov. 10, 1922	Knotts Island, N. C.
207784	-----	do	do	Sept. 23, 1922	May 8, 1923 ²	Algoma, Ontario.
207788	-----	do	do	do	Jan. 20, 1923 ²	Ocklocknee River, Fla.
207790	-----	do	do	do	Dec. 12, 1922	Stormy Point, N. J.
207791	-----	do	do	do	Jan. 11, 1923	Mouth of South Santee River, S. C.
207794	-----	do	do	do	Nov. 4, 1922	Rice Lake, Ontario.
207901	-----	do	do	Sept. 27, 1922	Dec. 1, 1922 ²	Presque Isle Bay, north shore Lake Ontario, Ontario.
207902	-----	do	do	do	Jan. 25, 1923	Kent Island, Md.
207906	-----	do	do	do	Dec. 7, 1922	Hog Island Bay, Va.
207908	-----	do	do	do	Nov. 6, 1922	Long Point, north shore Lake Erie, Ontario.
207911	-----	do	do	do	Nov. 13, 1922	Fishing Bay, Dorchester County, Md.
207925	-----	do	do	Sept. 28, 1922	Jan. 24, 1923	Lower Peach Tree, Ala.
207927	-----	do	do	do	Dec. 23, 1922	Bombay Hook, Del.
207929	-----	do	do	do	Nov. 21, 1922	Saugatuck, Mich. (18 mi. SE.).
207935	-----	do	do	Sept. 29, 1922	Dec. 21, 1922	Currituck Shooting Club, N. C.
207940	-----	do	do	Sept. 30, 1922	Nov. 21, 1922	Far Bay, Md.
207943	-----	do	do	do	Nov. 10, 1922	Potomac Creek, Va.
207946	-----	do	do	do	Nov. 23, 1922	St. Clair Flats, Mich..
207954	-----	do	do	Oct. 1, 1922	Jan. 10, 1923	Point Auber, La.
207955	-----	do	do	do	Nov. 11, 1922	Mud Lake, Ontario.
207957	-----	do	do	do	Oct. 25, 1922	Brighton, Ontario.
207961	-----	do	do	do	Oct. 20, 1922	Bono, Ohio.
†207968	-----	do	do	Oct. 2, 1922	Oct. 26, 1922	Lake Seugog, Ontario.
†207978	-----	do	do	do	Oct. 10, 1922	Do.
207980	-----	do	do	do	Nov. 15, 1922	Georgian Bay, Ontario.
207982	-----	do	do	do	Dec. 12, 1922	Houma, La. (15 mi. S.).
207989	-----	do	do	Oct. 3, 1922	Oct. 28, 1922	Zephyr, Ontario.
†207991	-----	do	do	do	Nov. 6, 1922	Lake Seugog, Ontario.
207994	-----	do	do	do	Dec. 1, 1922	Monroe, Mich. (about 20 mi. N.).
228406	-----	do	do	Oct. 6, 1922	Feb. 1, 1923	Charles City, Va.
228408	-----	do	do	do	Oct. 12, 1922	Rice Lake, Ontario.
228412	-----	do	do	Oct. 7, 1922	Dec. 12, 1922	Snow Lake, Ark. (5 mi. W.).
228420	-----	do	do	do	Nov. 5, 1922	Orland, Ind.
228421	-----	do	do	do	Jan. 10, 1923	Upper Chester River, Md.
†228429	-----	do	do	do	Oct. 15, 1922	Lake Seugog, Ontario.
228434	-----	do	do	do	Jan. 22, 1923	Gillette, Ark.
228436	-----	do	do	do	Nov. 7, 1922	Belleville, Ontario. (12 mi. E.).
†228440	-----	do	do	do	Oct. 16, 1922	Lake Seugog, Ontario.

² Date approximate.

Black Duck—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
228450	---	H. S. Osler	Lake Scugog, Ontario.	Oct. 8, 1922	Jan. 2, 1923	Big Spring, Ky.
228454	---	do.	do.	do.	Jan. 1, 1923	Matagorda Bay, Tex.
228456	---	do.	do.	do.	Dec. 28, 1922	Hog Island Bay, Va.
228457	---	do.	do.	do.	Jan. 6, 1923	Nanticoke River, Md.
228458	---	do.	do.	do.	Dec. 29, 1922	Stevenson, Ala.
228461	---	do.	do.	do.	Nov. 20, 1922	"Canadian Marsh," Mich.
228467	---	do.	do.	do.	Nov. 10, 1922 ²	Tilbury, Ontario (3 mi N.).
228471	---	do.	do.	do.	Dec. 28, 1922	Fort Mott, N. J.
†228480	---	do.	do.	do.	Oct. 15, 1922	Lake Scugog, Ontario.
228482	---	do.	do.	do.	Oct. 27, 1922	Massillon, Ohio (8 mi. N.).
†228487	---	do.	do.	do.	Oct. 16, 1922	Lake Scugog, Ontario.
228499	---	do.	do.	Oct. 10, 1922	Nov. 20, 1922	Currituck Sound, N. C.
228500	---	do.	do.	do.	Nov. 13, 1922	Belleville, Ontario (12 mi. E.).
228502	---	do.	do.	do.	Jan. 17, 1923	Savannah, Ga.
228519	---	do.	do.	do.	Oct. 16, 1922	Catskill, N.Y. (1 mi. N.).
228529	---	do.	do.	Oct. 13, 1922	Nov. 10, 1922	Long Point, Ontario.
228537	---	do.	do.	do.	Nov. —, 1922	South Fork of Halston River, Va.
228541	---	do.	do.	do.	Oct. —, 1922	Thirty Thousand Islands, Ontario.
†228544	---	do.	do.	do.	Oct. 20, 1922	Lake Scugog, Ontario.
228450	---	do.	do.	do.	Nov. 11, 1922	Aberdeen Proving Ground, Md.
228555	---	do.	do.	Oct. 16, 1922	Nov. 30, 1922	Toledo, Ohio (30 mi. E.).
†228562	---	do.	do.	do.	Oct. 16, 1922	Lake Scugog, Ontario.
228566	---	do.	do.	do.	Jan. 1, 1923	Boque Sound, N. C.
†228567	---	do.	do.	Oct. 20, 1922	Nov. —, 1922	Lake Scugog, Ontario.
228578	---	do.	do.	do.	Nov. 3, 1922	Scugog River, Ontario.
228582	---	do.	do.	do.	Dec. 4, 1922 ²	Savannah, Ga.
228590	---	do.	do.	do.	Nov. 23, 1922	Thomasville, Ga. (20 mi. S.).
†228598	---	do.	do.	do.	Oct. 25, 1922	Lake Scugog, Ontario.
†228604	---	do.	do.	Oct. 21, 1922	Nov. 6, 1922	Do.
228608	---	do.	do.	do.	Nov. 26, 1922	Waynesboro, Ga.
228623	♀	do.	do.	do.	Dec. 23, 1922	Reydel, Ark.
228670	---	do.	do.	Nov. 6, 1922	Nov. 25, 1922	Dunnville, Ontario.
228680	---	do.	do.	Nov. 11, 1922	Dec. 7, 1922	Gray Court, S. C.
228692	---	do.	do.	Nov. 13, 1922	Dec. 10, 1922 ²	Pine Brook, N. J.
228699	---	do.	do.	Nov. 16, 1922	Nov. 20, 1922	Point Breese, Orleans County, N. Y.

Gadwall: *Chaulelasmus streperus*

504301	---	E. A. McIlhenny.	Avery Island, La.	Dec. 13, 1922	Jan. 4, 1923	St. Marys Parish, La.
504309	---	do.	do.	do.	Jan. 10, 1923	Delcambre, La.
†202473	---	J. C. Silver	Unity, Saskatchewan.	Aug. 15, 1922	Sept. 23, 1922	Unity, Saskatchewan.
202474	---	do.	do.	Aug. 17, 1922	Nov. 16, 1922	Randall County, Tex. ⁸

² Date approximate.⁸ Shot and wing broken but reported as alive and receiving care from the hunter.

Green-winged Teal: *Nettion carolinense*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
†5040	---	O. J. Murie	Fairbanks, Alaska.	Aug. 8, 1921	Sept. 1, 1921	Fairbanks, Alaska (5 mi. W.).
*43070	♀	E. A. McIlhenny.	Avery Island, La.	Mar. 4, 1922	Nov. 6, 1922	Pekin, Ill. (1½ mi. N.).
*43080	♂	do.	do.	do.	June 1, 1923	Lac La Ronge, Saskatchewan.
*43098	♂	do.	do.	Mar. 16, 1922	Nov. 11, 1922	McHenry, N. Dak.
*43110	♂	do.	do.	Feb. 12, 1917	Apr. 28, 1920	Badger, Minn.
101461	♀	do.	do.	Mar. 4, 1922	Nov. 21, 1922	Avery Island, La.
101489	♂	do.	do.	do.	Oct. 17, 1922	Herman, Minn. (9 mi. N.).
101499	♂	do.	do.	do.	Jan. 28, 1923	Near Basile, La.
102223	♀	do.	do.	Mar. 21, 1922	Sept. 26, 1922	Platte County, Nebr.
504054	---	do.	do.	Nov. 16, 1922	Jan. 20, 1923	Elton, La.
504258	---	do.	do.	Nov. 28, 1922	Dec. 28, 1922	Iberia Parish, La.
504263	---	do.	do.	Dec. 12, 1922	Dec. 12, 1922	Lafayette, La.
504269	---	do.	do.	do.	Jan. —, 1923	Derouen P. O., La.
504321	---	do.	do.	Dec. 15, 1922	Jan. 20, 1923	Belair, La.
504334	---	do.	do.	do.	Jan. 18, 1923	Gueydan, La.
504388	---	do.	do.	Dec. 21, 1922	Jan. 3, 1923	Jefferson Island, La.
504441	---	do.	do.	Dec. 27, 1922	May 18, 1923	Sundridge, Ontario.
504528	---	do.	do.	Jan. 9, 1923	Mar. 21, 1923 ²	Benton County, Mo.
504558	---	do.	do.	Jan. 18, 1923	Jan. 25, 1923 ²	Eunice, La. (6 mi. E.).
*24012	♀	A. A. Allen	Union Springs, N. Y.	Mar. 28, 1923	Mar. 30, 1923	Seneca Falls, N. Y.

Blue-winged Teal: *Querquedula discors*

*43022	♂	E. A. McIlhenny.	Avery Island, La.	Mar. 4, 1922	Jan. 22, 1923	Delcambre, La.
*43048	♀	do.	do.	do.	Nov. 18, 1922	Gueydon, La. (20 mi. S.).
*43054	♀	do.	do.	do.	Sept. 1, 1922	Victoria, Kans.
*43143	♂	do.	do.	Feb. 19, 1922	Aug. 31, 1922	Brownwood, Tex.
101458	♀	do.	do.	Mar. 4, 1922	Nov. 2, 1922	Crowley, La.
101474	♂	do.	do.	do.	Jan. 25, 1923	Delcambre, La. (2 mi. SE.).
101708	♀	do.	do.	Feb. 9, 1922	Jan. 12, 1923	Iberia Parish, La.
101722	♀	do.	do.	do.	Oct. 22, 1922	Whitewood Lake, S. Dak.
102208	♂	do.	do.	Mar. 23, 1922	Sept. 29, 1922	Blackbird, Nebr.
102244	♂	do.	do.	Mar. 21, 1922	Sept. 16, 1922	Sibley County, Minn.
102287	♂	do.	do.	Mar. 25, 1922	do.	Lake Traverse, Minn.
102294	♂	do.	do.	do.	Dec. 18, 1922 ²	Lafayette, La. (12 mi. S.).
102296	♀	do.	do.	do.	Oct. 13, 1922	Herington, Kans.
504017	---	do.	do.	Nov. 16, 1922	Jan. 29, 1923	Opelousas, La.
504025	---	do.	do.	do.	Dec. 18, 1922	Abbeville, La.
504039	---	do.	do.	do.	Apr. 24, 1923	Washington, Ark.
504065	♀	do.	do.	do.	Dec. 3, 1922	Houma, La. (30 mi. S.).
504088	---	do.	do.	Nov. 17, 1922	Dec. 24, 1922	Vermilion Parish, La.
504097	---	do.	do.	Nov. 21, 1922	Mar. 16, 1923	Portland, Ark.
504159	---	do.	do.	Nov. 23, 1922	Jan. 28, 1923	Belle Isle, La.
504171	---	do.	do.	do.	Dec. 18, 1922	Cow Island, La.
504174	---	do.	do.	do.	Dec. 8, 1922	Cade, La.
504175	---	do.	do.	do.	May 1, 1923 ²	Como, Miss.
504178	---	do.	do.	do.	Dec. 23, 1922	Erath, La.
504183	---	do.	do.	do.	Dec. 7, 1922	South shore Vermilion Bay, La.
504185	---	do.	do.	do.	Dec. 20, 1922	Vermilion Parish, La.

² Date approximate.

Blue-winged Teal—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
504192	-----	E. A. Mill-henny.	Avery Island, La.	Nov. 23, 1922	Dec. 13, 1922	Shell Canal, west of Opelousas, La.
504194	-----	do.	do.	do.	Jan. 15, 1923	Iberia Parish, La.
504199	-----	do.	do.	do.	Jan. —, 1923	Esterwood, La.
504213	-----	do.	do.	Nov. 28, 1922	Dec. 3, 1922	St. Martinsville, La.
504223	-----	do.	do.	do.	Dec. 9, 1922	St. Patrick, La.
504225	-----	do.	do.	do.	Dec. 10, 1922	Henry, La.
504241	♀	do.	do.	do.	do.	Houma, La. (8 mi. SW.).
504245	-----	do.	do.	do.	Jan. 1, 1923 ²	Youngsville, La.
504248	-----	do.	do.	do.	Jan. 20, 1923 ²	Creole, La.
504251	-----	do.	do.	do.	Dec. 9, 1922	North shore Vermilion Bay, La.
504253	-----	do.	do.	do.	Dec. —, 1922	Erath, La.
504276	-----	do.	do.	Dec. 12, 1922	Apr. —, 1923 ²	Leonville, La.
504338	-----	do.	do.	Dec. 15, 1922	Jan. 28, 1923	Lockport, La.
†504361	-----	do.	do.	Dec. 19, 1922	Dec. 20, 1922	Avery Island, La.
504364	-----	do.	do.	do.	Dec. 23, 1922	Erath, La.
504367	-----	do.	do.	Dec. 21, 1922	Dec. 22, 1922	Delcambre, La.
504391	-----	do.	do.	do.	May 15, 1923	Sandy Lake, Manitoba.
504398	-----	do.	do.	do.	Jan. 19, 1923	Abbeville, La.
504476	-----	do.	do.	Dec. 29, 1922	Jan. 28, 1923	Diamond P. O., La.
504509	-----	do.	do.	Jan. 7, 1923	Apr. 14, 1923	Moro, Ark. (3 mi. N.).
232575	♂	John Broeker ⁴	Portage des Sioux, Mo.	Apr. 18, 1923	May 22, 1923	Partridge Crop Lake, Saskatchewan.
4576	-----	H. S. Osler	Lake Scugog, Ontario.	Sept. 24, 1920	Dec. 9, 1920	Port of Spain, Trinidad.
4708	-----	do.	do.	Sept. 17, 1921	Oct. 11, 1922	Glen Elder, Kans.
4709	-----	do.	do.	do.	Sept. 26, 1921	Lake Scugog, Ontario (75 mi. SE.).
†4713	-----	do.	do.	do.	Oct. 6, 1921	Lake Scugog, Ontario.
4715	-----	do.	do.	do.	Oct. 12, 1921	Seagrave, Ontario.
4721	-----	do.	do.	do.	Oct. 14, 1921	Pigeon Lake, Ontario.
4726	-----	do.	do.	do.	Sept. 26, 1921	Scugog River, Ontario.
†4729	-----	do.	do.	Sept. 18, 1921	Fall, 1921	Lake Scugog, Ontario.
4732	-----	do.	do.	do.	Nov. 12, 1922	East Islip, Long Island, N. Y.
†4733	-----	do.	do.	do.	Fall, 1921	Lake Scugog, Ontario.
4867	-----	do.	do.	Sept. 22, 1921	Sept. 18, 1922	Middle Lake, Nicollet County, Minn.
4869	-----	do.	do.	do.	Sept. 15, 1922 ²	Arlington, S. Dak.
4856	-----	do.	do.	do.	Sept. 27, 1921	Scugog River, Ontario.
4858	-----	do.	do.	do.	Sept. 26, 1921	Long Point, Lake Erie, Ontario.
4875	-----	do.	do.	Sept. 24, 1921	Oct. 14, 1921	Rice Lake, Ontario.
5184	-----	do.	do.	Sept. 15, 1921	Apr. 15, 1923 ²	Lake Carrier, Miss.
†5186	-----	do.	do.	do.	Sept. 24, 1921	Lake Scugog, Ontario.
†207556	-----	do.	do.	Sept. 13, 1922	Oct. 26, 1922 ²	Do.
207590	-----	do.	do.	Sept. 14, 1922	Oct. 13, 1922	Ithaca, N. Y.
†207724	-----	do.	do.	Sept. 20, 1922	Oct. 21, 1922	Lake Scugog, Ontario.

Shoveler: *Spatula clypeata*

504546	♂	E. A. McIlhenny.	Avery Island, La.	Jan. 13, 1923	Jan. 15, 1923	Delcambre, La.
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² Date approximate.⁴ Under direction of Joseph Pulitzer, of St. Louis, Mo.

Pintail: *Dafila acuta tzitzihoa*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
102409	♂	F. C. Lincoln	Browning, Ill.	Mar. 5, 1922	Sept. 27, 1922	Roberts County, S. Dak.
102430	♀	do.	do.	Mar. 7, 1922	Sept. 17, 1922	Valentine, Nebr. (30 mi. S.).
102433	♀	do.	do.	do.	Jan. 28, 1923	Cameron Parish, La.
102471	♀	do.	do.	Mar. 8, 1922	Jan. 23, 1923	Jennings, La.
230208	♀	do.	do.	Nov. 18, 1922	Nov. 23, 1922	Beardstown, Ill.
230211	♂	do.	do.	do.	Dec. 9, 1922	Bath, Ill. (4 mi. S.).
230489	♀	do.	do.	Nov. 22, 1922	Nov. 24, 1922	Beardstown, Ill.
230635	♂	do.	do.	Nov. 23, 1922	Dec. 7, 1922	Bath, Ill.
230636	♂	do.	do.	do.	Dec. 19, 1922	Bélair, La.
*36150	♀	E. A. McIlhenny.	Avery Island, La.	Feb. 12, 1917	June —, 1921 ⁶	Ross, N. Dak.
*36222	♀	do.	do.	Feb. 2, 1917	Oct. 28, 1922	Alice, Tex.
*36229	♀	do.	do.	Feb. 12, 1917	Oct. 15, 1918 ²	Hay Lakes, Alberta.
*36233	♀	do.	do.	do.	Nov. 15, 1920	Derouen, La.
*36243	♀	do.	do.	do.	Oct. 21, 1917	Wilmont, Minn.
*36269	♀	do.	do.	do.	Sept. 15, 1919	Humboldt, Saskatchewan (4½ mi. NE.).
*36259	♀	do.	do.	do.	Oct. 5, 1919	Oshkosh, Wis.
*36272	♀	do.	do.	do.	Mar. —, 1918	Kingfisher County, Okla.
*36279	♀	do.	do.	do.	Nov. 25, 1919	Avery Island, La.
101647	♀	do.	Belle Isle Lake, La.	Feb. 17, 1922	Jan.-Feb., 1922	Jennings, La. (10 mi. SW.).
*35793	♀	A. A. Allen	Ithaca, N. Y.	Mar. 18, 1918	Sept. 22, 1920 ¹⁰	Camrose, Alberta.
†207964	♂	H. S. Osler	Lake Scugog, Ontario.	Oct. 1, 1922	Oct. 16, 1922	Lake Scugog, Ontario.
202404	---	H. L. Felt ⁷	Findlater, Saskatchewan.	July 9, 1922	Nov. 4, 1922	Camp Crook, S. Dak. (2 mi. W.).
202476	---	J. C. Silver ⁷	Unity, Saskatchewan.	Aug 17 1922	Sept. 23, 1922	Unity, Saskatchewan (3 mi. E.).

Canvasback: *Marila valisineria*

228780	♂	A. A. Allen	Ithaca, N. Y.	Feb. 5, 1923	Feb. 10, 1923	Branchport, N. Y.
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Scaup Duck: *Marila marila*

*25331	♀	A. A. Allen	Ithaca, N. Y.	Mar. 15, 1920	Dec. 10, 1920	Union Springs, N. Y.
*25332	♀	do.	Union Springs, N. Y. ¹¹	Mar. 20, 1920	Dec. 18, 1920	Levanna, N. Y.
101801	---	do.	Ithaca, N. Y.	Mar. 5, 1922	Nov. 11, 1922	Elm Beach, N. Y.
101819	♂	do.	do.	Feb. 28, 1922	Oct. 31, 1922 ²	Rochester, N. Y. (35 mi. E.).

² Date approximate.⁷ Under direction of Fred Bradshaw, of Regina, Saskatchewan.⁹ Had been dead a long time when found.¹⁰ Trapped at Avery Island, La., in February, 1918, by E. A. McIlhenny and shipped to Doctor Allen, at Ithaca, N. Y.¹¹ One wing clipped when released.

Lesser Scaup Duck: *Marila affinis*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
228773	♀	A. A. Allen...	McKinneys, south end of Cayuga Lake, N. Y.	Feb. 1, 1923	Mar. 1, 1923 ²	Seneca Lake, N. Y.

Ring-necked Duck: *Marila collaris*

101405	♂	E. A. McIlhenny.	Belle Isle Lake, La.	Feb. 17, 1922	Nov. 1, 1922	Solomon River, Kans
101407	♂	...do.....	...do.....	...do.....	May 12, 1923	Isle a la Crosse Lake, Saskatchewan (20 mi. NE.).
101427	♂	...do.....	...do.....	Feb. 21, 1922	Mar. 1, 1922 ²	Gueydan, La.
101540	♂	...do.....	...do.....	Feb. 17, 1922	Sept. 16, 1922	Franklin, Nebr.
101561	♂	...do.....	...do.....	...do.....	Mar. 10, 1922	Asbury, Mo. (2 mi. E.).
101568	♂	...do.....	...do.....	...do.....	Nov. 1, 1922	Vilas County, Wis.
101594	♀	...do.....	...do.....	...do.....	Oct. 10, 1922	Quincy, Ill.
101704	♂	...do.....	...do.....	Feb. 21, 1922	Nov. 2, 1922	Meeker County, Minn.
101720	♂	...do.....	...do.....	...do.....	Oct. 22, 1922	Shellmouth, Manitoba.
101730	♂	...do.....	...do.....	...do.....	Apr. 20, 1923 ²	Benson, Minn.
101747	♂	...do.....	...do.....	...do.....	Nov. 11, 1922 ²	Eastern part of Galveston County, Tex.
101757	♂	...do.....	...do.....	...do.....	May 25, 1923	The Barrier, Saskatchewan (40 mi. W. of The Pas, Man.).
*37304	-----	H. S. Osler....	Lake Scugog, Ontario.	Oct. 29, 1920	Jan. 5, 1921	Georgetown County, S. C.
4700	♂	...do.....	...do.....	...do.....	Nov. 23, 1920	Back Bay, Va.
†101122	♂	...do.....	...do.....	Oct. 16, 1921	Nov. 4, 1921	Lake Scugog, Ontario.

Bufflehead: *Charitonetta albeola*

*43985	♀	Verdi Burtch.	Branchport, N. Y.	Apr. 6, 1922	Apr. 17, 1922	Georgian Bay near Collingwood, Ontario.
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White-winged Scoter: *Oidemia deglandi*

†24127	♂	W. E. Smith..	South Chatham, Mass.	Jan. 30, 1923	Feb. 1, 1923	U. S. naval radio station, Chatham, Mass.
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White-faced Glossy Ibis: *Plegadis guarauna*

3539	-----	Alex Wetmore.	Mouth of Bear River, Utah.	July 3, 1916	Oct. 22, 1922	Lake Tulare, Tulare County, Calif. ¹²
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² Date approximate.

¹² Picked up while duck hunting; no gun-shot wounds on body; appeared to be weak from digestive trouble.

Great Blue Heron: *Ardea herodias herodias*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
*43965	-----	R. D. Book	Corning, Ohio (1/4 mi. N. W.)	Apr. 21, 1920	Jan. 25, 1921	Litchfield, Mich. (2 mi. S. and 1/2 mi. W.).

Ward Heron: *Ardea herodias wardi*

†233311	-----	R. D. Camp	Green Island, Cameron County, Tex.	May 14, 1923	May 15, 1923	Green Island, Cameron County, Tex.
†236393	-----	do	do	July 7, 1923	July 9, 1923	Do.

Snowy Egret: *Egretta candidissima*

†210793	-----	R. D. Camp	Green Island, Cameron County, Tex.	May 2, 1923	May 20, 1923	Green Island, Cameron County, Tex.
3615	-----	Alex Wetmore	Mouth of Bear River, Utah.	July 3, 1916	Jan. 20, 1923	Near Escuinapa, Sinaloa, Mexico.

Reddish Egret: *Dichromanassa rufescens*

233347	-----	R. D. Camp	Green Island, Cameron County, Tex.	May 15, 1923	Aug. 10, 1923	Galveston, Tex.
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Black-crowned Night Heron: *Nycticorax nycticorax naevius*

201635	-----	S. G. Emilio	Danvers, Mass.	July 30, 1922	Sept. 25, 1922	North Andover, Mass.
201908	-----	L. B. Fletcher	Barnstable, Mass.	June 17, 1922	Sept. 4, 1922	Beach Bluff, Mass.
201983	-----	do	do	do	Aug. 20, 1922	Fryeburg, Me.
202004	-----	do	do	do	Aug. 7, 1922	Kennebunkport, Me.
*24506	-----	J. C. Phillips	Hamilton, Mass.	June 3, 1915	May 1, 1920	North Cromwell, Conn.
*24536	-----	do	do	June 10, 1915	June 4, 1921	Rye Beach, N. H.

Florida Gallinule: *Gallinula chloropus cachinnans*

5122	-----	H. S. Osler	Lake Scugog, Ontario.	Aug. 31, 1921	Sept. 4, 1922	Lake Scugog, Ontario.
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Coot: *Fulica americana*

*43244	-----	E. A. McPhenny	Avery Island, La.	May 2, 1921	Sept. 12, 1921	Liberty, Miss.
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Mourning Dove: *Zenaidura macroura*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
19008	-----	W. I. Lyon	Waukegan, Ill.	June 18, 1921	Sept. 23, 1921	Nashville, Tenn. (20 mi. S.).
†19010	-----	do.	do.	July 7, 1921	Sept. 1, 1921	Waukegan, Ill.
10119	-----	S. E. Perkins	Indianapolis, Ind.	June 19, 1922	Nov. 25, 1922 ¹	Marion, Ala.
23350	-----	do.	do.	May 17, 1922	Aug. 23, 1922	Attica, Ind.
8903	♂	Mrs. B. P. Reed.	Lawrence, Kans.	May 12, 1922	June 6, 1923	Lawrence, Kans.
9903	-----	E. A. McIlhenny.	Avery Island, La.	Mar. 17, 1922	Sept. 30, 1922	Duson, La.
9933	-----	do.	do.	Mar. 13, 1922	Oct. 21, 1922	Delcambre, La.
9992	-----	do.	do.	Mar. 4, 1922	Sept. 29, 1922	New Iberia, La.
9993	-----	do.	do.	do.	Jan. 14, 1923	Avery Island, La.
*57721	-----	S. P. Baldwin	Gates Mill, Ohio.	June 7, 1921	June 12, 1923	Gates Mill, Ohio.
*42829	-----	William Pepper.	Newtown Square, Delaware County, Pa.	May 31, 1920	Jan. 23, 1921	Albany, Ga. (32 mi. S.).

Cooper Hawk: *Accipiter cooperi*

*23020	-----	G. I. Eadie and F. L. Burns.	Berwyn, Pa.	July 4, 1920	Apr. 6, 1922	Asheville, N. C.
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Red-shouldered Hawk: *Buteo lineatus*

3351	-----	L. W. Laird	Harper, Kans.	Aug. 17, 1922	Aug. 23, 1922	Duquoin, Kans. (5½ mi. NE.).
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Ferruginous Rough-leg: *Archibuteo ferrugineus*

*37998	-----	W. R. Felton	East Chouteau County, Mont.	July 2, 1916	Sept. 29, 1919	Harlowton, Mont.
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Bald Eagle: *Haliaeetus leucocephalus*

202114	-----	Herman Bat-terby	Oak Lake, Manitoba. ¹³	Nov. 23, 1922	Nov. 24, 1922	Hartney, Manitoba. (2 mi. W.)
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Sparrow Hawk: *Cerchneis sparveria*.

21531	-----	S. P. Baldwin	Gates Mills, Ohio.	June 18, 1916	July 12, 1917	Cleveland, Ohio
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¹ Date approximate.¹³ Wing-tipped bird. Released after wing had healed.

Short-eared Owl: *Asio flammeus*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
3065	♂	Mrs. B. P. Reed.	Lawrence, Kans. ¹⁴	Apr. 30, 1922	June 19, 1923	Perry, Kans. (1 mi. E.).

Barred Owl: *Strix varia*

*26028	-----	M. S. Crcsby.	Rhinebeck, N. Y.	May 29, 1920	Jan. 9, 1921	East Park, N. Y.
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Screech Owl: *Otus asio*

†201351	-----	Johnson Neff.	Marionville, Mo.	July 30, 1922	Sept. 1, 1922	Marionville, Mo.
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Great Horned Owl: *Bubo virginianus*

3067	-----	Mrs. B. P. Reed.	Lawrence, Kans.	Apr. 30, 1922	June 5, 1923	Lawrence, Kans.
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Hairy Woodpecker: *Dryobates villosus*

†19183	-----	W. I. Lyon....	Waukegan, Ill....	Nov. 4, 1922	Nov. 12, 1922	Waukegan, Ill.
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Downy Woodpecker: *Dryobates pubescens*

*52415	♀	W. I. Lyon....	Waukegan, Ill....	Feb. 18, 1921	Feb. 10, 1922	Waukegan, Ill.
*47558	♂	Miss K. M. Hempel.	Elkader, Iowa....	Feb. 8, 1921	Nov. 27, 1922	Elkader, Iowa.
*48438	♀	-----do-----	-----do-----	Mar. 8, 1921	Nov. 28, 1922	Do.
*54892	♂	-----do-----	-----do-----	Feb. 12, 1921	May 12, 1923	Do.
*54900	♀	-----do-----	-----do-----	Dec. 2, 1921	Jan. 25, 1923	Do.
*55002	♀	-----do-----	-----do-----	Feb. 27, 1922	Dec. 19, 1922	Do.
*55005	♀	-----do-----	-----do-----	Dec. 2, 1921	Nov. 29, 1922	Do.
22265	♂	Mrs. L. D. Morey.	Chevy Chase, Md.	Mar. 2, 1922	Dec. 11, 1922	Chevy Chase, Md.
*47935	♂	J. Van Tyne..	Ann Arbor, Mich. ¹	Oct. 16, 1921	Feb. 17, 1922	Ann Arbor, Mich.

Red-headed Woodpecker: *Melanerpes erythrocephalus*

†16163	-----	Mrs. B. P. Reed.	Lawrence, Kans.	June 7, 1922	June 9, 1922	Lawrence, Kans.
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¹⁴ Wounded. Cared for through winter.

Red-bellied Woodpecker: *Centurus carolinus*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
*31778	-----	S. P. Baldwin	Thomasville, Ga.	Mar. 7, 1916	Mar. 9, 1917	Thomasville, Ga.
*31778	-----	do	do	do	Feb. 16, 1920	Do.
*53069	-----	do	do	Feb. 15, 1920	Feb. 25, 1921	Do.

Flicker: *Colaptes auratus*

†15209	-----	Mrs. B. P. Reed	Lawrence, Kans.	June 8, 1921	June 8, 1921	Lawrence, Kans.
104406	♂	W. G. Vinal	Wellfleet, Mass.	June 24, 1922	Nov. 4, 1922	Eastham, Cape Cod, Mass.

Nighthawk: *Chordeiles virginianus*

†104155	-----	Hoyes Lloyd	Ottawa, Ontario.	Aug. 4, 1922	Aug. 6, 1922	Ottawa, Ontario.
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Chimney Swift: *Chaetura pelagica*

*†51355	-----	Mrs. B. P. Reed	Lawrence, Kans.	July 14, 1921	Aug. 1, 1921	Lawrence, Kans.
12530	-----	do	do	July 14, 1922	Apr. 24, 1923	Do.
†30137	-----	H. E. Childs	Sweden, Me.	July 12, 1922	July 25, 1922	Sweden, Me.
*38461	-----	S. P. Baldwin	Gates Mills, Ohio	June 6, 1916	June 12, 1917	Gates Mills, Ohio.
*38461	-----	do	do	do	June 9, 1921	Do.
*38461	-----	do	do	do	June 7, 1922	Do.
*38461	-----	do	do	do	July 3, 1923	Do.

Phoebe: *Sayornis phoebe*

†11626	-----	P. F. Foran	Ottawa, Ontario.	July 11, 1921	Aug. 4, 1921	Ottawa, Ont.
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Wood Pewee: *Myiochanes virens*

†74569	-----	A. W. Taylor	Unity, Me.	July 25, 1922	July 26, 1922	Unity, Me.
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Horned Lark: *Otocoris alpestris*

67763	-----	Allan Keniston.	Marthas Vineyard, Mass.	Feb. 18, 1923	Apr. 18, 1923	Port au Port, Newfoundland.
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Blue Jay: *Cyanocitta cristata*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
18377		W. I. Lyon	Melbourne, Fla.	May 30, 1922	June 18, 1923	Melbourne, Fla.
*1916		S. P. Baldwin	Thomasville, Ga.	Mar. 28, 1916	Feb. 15, 1920	Thomasville, Ga.
*1916		do	do	do	Mar. 6, 1921	Do.
*1929		do	do	Feb. 17, 1917	Feb. 17, 1917	Do.
*1929		do	do	do	Jan. —, 1921	Do.
*31772		do	do	Feb. —, 1916	Mar. 23, 1920	Do.
*31775		do	do	Mar. 1, 1916	Mar. 26, 1921	Do.
*41897		do	do	Mar. 12, 1917	Feb. 27, 1920	Do.
*41897		do	do	do	Mar. 11, 1921	Do.
*53075		do	do	Feb. 16, 1920	Mar. 28, 1921	Do.
*53080		do	do	do	Mar. 30, 1921	Do.
*55218		do	do	Mar. 16, 1921	Mar. 29, 1922	Do.
18328		W. I. Lyon	Waukegan, Ill.	Oct. 22, 1921	May 10, 1922	Waukegan, Ill.
18329		do	do	Nov. 23, 1921	June 18, 1922	Do.
†23593		do	do	July 8, 1922	Aug. 20, 1922	Do.
18285		Miss K. M. Hempel	Elkader, Iowa	Mar. 30, 1922	Nov. 8, 1922	Elkader, Iowa.
18295		do	do	June 8, 1921	June 12, 1922	Do.
18296		do	do	June 7, 1921	Dec. 14, 1922	Do.
18298		do	do	June 24, 1921	Jan. 24, 1922	Do.
18298		do	do	do	June 29, 1922	Do.
18298		do	do	do	Dec. 14, 1922	Do.
18298		do	do	do	June 28, 1923	Do.
103569		do	do	May 17, 1922	June 16, 1923	Do.
103570		do	do	May 22, 1922	June 13, 1923	Do.
†103580		do	do	June 3, 1922	June 4, 1922	Do.
106235		do	do	Nov. 26, 1922	June 27, 1923	Do.
†103983		L. W. Laird	Harper, Kans.	Aug. 19, 1922	Sept. 12, 1922	Harper, Kans.
17208		E. U. Ufford	Auburndale, Mass.	Apr. 23, 1922	May 29, 1923	Auburndale, Mass.
†10102		A. S. Warthin	Ann Arbor, Mich.	Apr. 6, 1922	Apr. 7, 1922	Ann Arbor, Mich.
103179		F. N. Wilson	do	Oct. 3, 1922	Apr. 26, 1923	Do.
†9407		A. F. and E. A. Satterthwait	Webster Groves, Mo.	June 5, 1922	June 12, 1922	Webster Groves, Mo.
†9408		do	do	June 10, 1922	do	Do.
†19912		do	do	do	June 14, 1922	Do.
†113411		E. C. Weeks	Sanbornton, N. H.	Mar. 1, 1923	Mar. 15, 1923	Sanbornton, N. H.
*42090		R. H. Howland	Upper Montclair, N. J.	Feb. 2, 1921	May 28, 1921	Upper Montclair, N. J.
*57903		M. S. Crosby	Rhinebeck, N. Y.	Jan. 17, 1922	Dec. 24, 1922	Rhinebeck, N. Y.
*41273		S. P. Baldwin	Gates Mills, Ohio	May 13, 1919	July 11, 1920	Gates Mills, Ohio.
*54912	♀	O. L. Mitchell	Cuyahoga Falls, Ohio.	Dec. 19, 1920	May 2, 1921	Cuyahoga Falls, Ohio.

Crow: *Corvus brachyrhynchos*

201618		W. A. Oswald	Shawbridge, Quebec.	Aug. 26, 1922	Sept. 7, 1922	Westmount, Quebec.
†24351		G. E. Allen	Plainfield, Mass.	June 9, 1922	July 5, 1922	Plainfield, Mass.
†24354		do	do	June 16, 1923	June 30, 1923	Do.
228305		C. E. Sanborn	Stillwater, Okla.	Jan. 2, 1923	Apr. 15, 1923	Woodstock, Minn.
*22368		F. L. Burns	Berwyn, Pa.	May 14, 1914	May 17, 1920	Phoenixville, Pa.

Fish Crow: *Corvus ossifragus*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
102335	-----	E. A. McIlhenny.	Avery Island, La.	Mar. 31, 1922	June 14, 1923	Iberia Parish, La.

Cowbird: *Molothrus ater*

66014	-----	W. A. Ruffin....	Auburn, Ala..	Mar. 13, 1923	Mar. 11, 1923 ¹⁵	Harrogate, Tenn.
†70107	-----	do.....	do.....	Mar. 15, 1923	Mar. 20, 1923	Auburn, Ala.
27551	♂	Frank Novak....	Fairfield, Conn	Apr. 13, 1922	Dec. 21, 1922	Savannah, Ga. (10 mi W.).
13358	♂	George Roberts..	Lake Forest, Ill.	Apr. 21, 1922	May 3, 1923	Lake Forest, Ill.
13360	♂	do.....	do.....	Apr. 30, 1922	Apr. 18, 1923	Do
†11483	-----	Mrs. B. P. Reed..	Lawrence, Kans.	June 23, 1921	June 26, 1921	Lawrence, Kans.
†31347	-----	A. W. Taylor....	Unity, Me....	July 16, 1922	July 17, 1922	Unity, Me.
*32945	♂	Verdi Burtch....	Branchport, N. Y.	Oct. 17, 1921	Feb. 12, 1922	Youngsville, N. C.

Meadowlark: *Sturnella magna*

†112360	-----	J. A. Neff.....	Marionville, Mo.	June 1, 1923	June 3, 1923	Marionville, Mo.
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Baltimore Oriole: *Icterus galbula*

†12737	-----	Mary F. Hobart..	Needham Heights, Mass.	June 18, 1922	June 18, 1922	Needham Heights, Mass.
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Purple Grackle: *Quiscalus quiscula quiscula*

34538	-----	Miss Esther Heacock.	Wyncote, Pa..	Apr. 10, 1917	June —, 1920	Jenkintown, Pa.
†109730	-----	J. F. Kilgus....	Williamsport, Pa.	Apr. 6, 1923	Apr. 30, 1923	Williamsport, Pa.
8601	-----	A. J. Middleton..	Jeffersonville, Pa.	July 29, 1921	May 10, 1922	Jeffersonville, Pa.

¹⁵ Obviously an error, reported under date of March 27, date of capture may have been March 21.

Bronzed Grackle: *Quiscalus quiscula aeneus*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
†18363	♂	W. I. Lyon.....	Waukegan, Ill.	Apr. 20, 1922	June 13, 1922	Waukegan, Ill.
23501		do.....	do.....	June 24, 1922	Nov. 30, 1922	Fillmore, Ill.
23594		do.....	do.....	July 8, 1922	July 28, 1922	Great Lakes, Ill.
113191	♀	do.....	do.....	Apr. 18, 1922	June 3, 1923	Waukegan, Ill.
†103925		F. N. Hadley...	Whiting, Ind..	May 30, 1922	May 31, 1922	Whiting, Ind.
†219504		W. W. Hollister.	Clear Lake, Iowa.	June 1, 1923	June 4, 1923	Clear Lake, Iowa.
*†57950		Dayton Stoner..	Iowa City, Iowa.	May 30, 1921	May 31, 1921	Iowa City, Iowa.
†18463	♂	do.....	do.....	Apr. 17, 1922	Apr. 27, 1922	Do.
†23899		C. B. Floyd.....	Auburndale, Mass.	May 3, 1922	June 2, 1923	Auburndale, Mass.
103739		do.....	do.....	Sept. 11, 1922	Nov. 7, 1922	Elizabeth, N. J.
†109962		R. Lloyd.....	Davidson, Sask.	May 6, 1923	May 21, 1923	Davidson, Sask.

Purple Finch: *Carpodacus purpureus*

30449	♂	Mrs. W. K. Harrington.	Norwalk, Conn.	May 8, 1922	Jan. 29, 1923	Norwalk, Conn.
36603	♀	do.....	do.....	Jan. 16, 1923	Mar. 6, 1923	Fairfield, Conn.
66137	♂	Frank Novak...	Fairfield, Conn.	Jan. 22, 1923	Feb. 12, 1923	Demarest, N. J.
66146		do.....	do.....	do.....	Mar. 12, 1923	Do.
66200	♂	do.....	do.....	Jan. 26, 1923	Feb. 18, 1923	Norwalk, Conn.
†32035	♀	W. I. Lyon.....	Waukegan, Ill.	Feb. 10, 1923	Feb. 21, 1923	Waukegan, Ill.
†32036	♀	do.....	do.....	do.....	Feb. 16, 1923	Do.
†32041	♀	do.....	do.....	Feb. 11, 1923	Feb. 14, 1923	Do.
†32047		do.....	do.....	Feb. 12, 1923	do.....	Do.
66576	♂	R. B. Harding..	Cohasset, Mass.	Feb. 4, 1923	Mar. 22, 1923	Wellesley, Mass.
25496	♂	Mrs. E. A. Her- rick.	Topsfield, Mass.	Apr. 24, 1922	Apr. 27, 1923	Topsfield, Mass.
26396	♂	do.....	do.....	May 3, 1922	May 14, 1923	Do.
26399	♂	do.....	do.....	May 2, 1922	May 10, 1923	Do.
27057	♂	do.....	do.....	May 10, 1922	June 20, 1922	Do.
27058	♀	do.....	do.....	do.....	Apr. 19, 1923	Do.
27060	♀	do.....	do.....	do.....	Apr. 25, 1923	Do.
27068	♀	do.....	do.....	May 6, 1922	Apr. 22, 1923	Do.
27080	♀	do.....	do.....	May 3, 1922	Mar. 30, 1923	Do.
28230	♂	do.....	do.....	May 27, 1922	Apr. 24, 1923	Do.
29642	♂	do.....	do.....	May 12, 1922	May 10, 1923	Do.
29643	♀	do.....	do.....	May 14, 1922	May 22, 1923	Do.
29644	♀	do.....	do.....	May 17, 1922	May 1, 1923	Do.
29652	♀	do.....	do.....	May 23, 1922	Apr. 19, 1923	Do.
74201	♂	do.....	do.....	May 31, 1922	Apr. 26, 1923	Do.
74202	♀	do.....	do.....	June 4, 1922	Apr. 20, 1923	Do.
74205	♂	do.....	do.....	June 8, 1922	Apr. 30, 1923	Do.
74206	♀	do.....	do.....	June 11, 1922	Apr. 22, 1923	Do.
74207	♀	do.....	do.....	do.....	May 20, 1923	Do.
74211	♀	do.....	do.....	June 14, 1922	May 9, 1923	Do.
74213	♂	do.....	do.....	June 15, 1922	Apr. 24, 1923	Do.
74221	♀	do.....	do.....	Aug. 4, 1922	May 16, 1923	Do.
74223	♂	do.....	do.....	Aug. 15, 1922	Apr. 13, 1923	Do.
74238	♂	do.....	do.....	Aug. 23, 1922	Apr. 18, 1923	Do.
74241		do.....	do.....	Aug. 8, 1922	Apr. 28, 1923	Do.
74243	♀	do.....	do.....	July 23, 1922	May 6, 1923	Do.

Purple Finch—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
74245	♀	Mrs. E. A. Her- rick.	Topsfield, Mass.	July 13, 1922	Apr. 26, 1923	Topsfield, Mass.
74249	♂	do	do	July 4, 1922	May 18, 1923	Do.
*51506		H. G. Higbee	Sharon, Mass.	Sept. 12, 1921	May 17, 1923	Foxboro, Mass.
29238	♀	do	do	Feb. 9, 1923	Mar. 11, 1923	Brockton, Mass.
55123	♂	Mary F. Hobart	N e e d h a m Heights, Mass.	Feb. 16, 1923	Mar. 28, 1923	Wellesley, Mass.
†66614		Mrs. A. B. Pratt	Middleboro, Mass.	Mar. 7, 1923	Apr. 16, 1923	Middleboro, Mass.
†67001	♂	G. H. Priest	B r o c k t o n, Mass.	Feb. 4, 1923	Feb. 12, 1923	Brockton, Mass.
30943	♀	Mrs. H. G. Whit- tle.	C o h a s s e t, Mass.	Jan. 18, 1923	Mar. 16, 1923	Wellesley, Mass.
30602		M. J. Magee	Sault Ste. Ma- rie, Mich.	June 25, 1922	May 12, 1923	Sault Ste. Marie, Mich.
30609	♂	do	do	July 1, 1922	May 11, 1923	Do.
30622		do	do	July 11, 1922	Apr. 22, 1923	Do.
30625		do	do	do	May 12, 1923	Do.
30648	♂	do	do	July 18, 1922	do	Do.
†31169		do	do	Aug. 28, 1922	Sept. 27, 1922	Do.
103609	♂	do	do	July 28, 1922	Apr. 27, 1923	Do.
103611		do	do	do	Apr. 28, 1923	Do.
†103629		do	do	July 29, 1922	Aug. 30, 1922	Do.
103644	♂	do	do	Aug. 1, 1922	May 12, 1923	Do.
†103675		do	do	Aug. 8, 1922	Aug. 14, 1922	Do.
†39906		H. E. Childs	Providence, R. I.	Feb. 27, 1923	Mar. 1, 1923	Providence, R. I.
†38732		Mrs. H. C. Miller.	Racine, Wis.	May 1, 1923	May 1, 1923	Racine, Wis.

House Finch: *Carpodacus mexicanus frontalis*

†52057		J. E. Law	Altadena, Calif. (15 mi. E.)	June 23, 1923	July 2, 1923	Altadena, Calif. (15 mi E.).
†52058		do	do	do	July 4, 1923	Do.

Goldfinch: *Astragalinus tristis*

54441		Mrs. J. E. Carth.	Wellesley, Mass.	Mar. 13, 1923	May 9, 1923	Topsfield, Mass.
†38496	♀	Mrs. E. A. Herrick.	Topsfield, Mass.	Jan. 24, 1923	Mar. 1, 1923	Do.
†38498	♀	do	do	Jan. 27, 1923	Apr. 18, 1923	Do.

Vesper Sparrow: *Poocetes gramineus*

†43682		R. H. Carter	Muscow, Sas- katchewan.	May 20, 1923	June 2, 1923	Muscow, Saskatchewan.
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White-Crowned Sparrow: *Zonotrichia leucophrys leucophrys*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
6637	-----	J. E. Law-----	Los Angeles, Calif.	Jan. 12, 1922	Dec. 21, 1922	Los Angeles, Calif.

Gambel Sparrow: *Zonotrichia leucophrys gambeli*

*48126	-----	J. E. Law-----	Los Angeles, Calif.	Oct. 6, 1921	Dec. 29, 1922	Los Angeles, Calif.
*48127	-----	do-----	do-----	Oct. 7, 1921	Apr. 9, 1922	Do.

Nuttall Sparrow: *Zonotrichia leucophrys nuttalli*

6630	-----	J. E. Law-----	Los Angeles, Calif.	Jan. 3, 1922	Dec. 28, 1922	Los Angeles, Calif.
6631	-----	do-----	do-----	Jan. 7, 1922	Dec. 29, 1922	Do.
6632	-----	do-----	do-----	do-----	Dec. 21, 1922	Do.

Golden-crowned Sparrow: *Zonotrichia coronata*

*49004	-----	Mrs. A. S. Allen.	Berkeley, Calif.	Mar. 3, 1920	Oct. 25, 1921	Berkeley, Calif.
*49004	-----	do-----	do-----	do-----	Jan. 25, 1922	Do.

White-throated Sparrow: *Zonotrichia albicollis*

*51978	-----	A. S. Allen-----	Berkeley, Calif.	Jan. 25, 1922	Nov. 29, 1922	Berkeley, Calif.
*51742	-----	Frank, Novak	Fairchild, Conn.	Sept. 28, 1922	Jan. 12, 1923	Fairfield, Conn.
13921	-----	A. A. Saunders	do-----	Apr. 22, 1922	Oct. 29, 1922	Do.
30560	-----	do-----	do-----	Dec. 1, 1922	Mar. 31, 1923	Do.
*51674	-----	Miss M. J. Fellow	Washington, D. C.	Oct. 26, 1920	Feb. 22, 1921	Washington, D. C.
*38160	-----	S. P. Baldwin.	Thomasville, Ga.	Mar. 5, 1916	Mar. 7, 1917	Thomasville, Ga.
*38160	-----	do-----	do-----	do-----	Feb. 25, 1920	Do.
*38160	-----	do-----	do-----	do-----	Mar. 17, 1921	Do.
*38160	-----	do-----	do-----	do-----	Mar. 27, 1921	Do.
*45405	-----	do-----	do-----	Feb. 19, 1920	Mar. 25, 1921	Do.
*48603	-----	do-----	do-----	Mar. 5, 1921	Mar. 29, 1922	Do.
*48698	-----	do-----	do-----	Mar. 17, 1921	Apr. 5, 1922	Do.
*48752	-----	do-----	do-----	Mar. 28, 1921	Mar. 22, 1922	Do.
*52735	-----	W. I. Lyon-----	Waukegan, Ill.	Oct. 10, 1921	Mar. 20, 1922	Waukegan, Ill.
†8758	-----	do-----	do-----	Oct. 11, 1922	Oct. 23, 1922	Do.
†17074	-----	do-----	do-----	Oct. 27, 1922	Nov. 12, 1922	Do.
†26737	-----	K. G. McDougal.	Winnipeg, Manitoba.	Sept. 19, 1922	Sept. 22, 1922	Winnipeg, Manitoba.
28322	♀	R. D. Sanders.	West Peabody, Mass.	May 5, 1922	May 5, 1923	West Peabody, Mass.
*50006	♂	B. S. Bowditch	Demarest, N. J.	Apr. 30, 1920	Aug. 31, 1921	Demarest, N. J.
*47134	-----	R. H. Howland.	Upper Montclair, N. J.	Feb. 20, 1921	Dec. 25, 1921	Upper Montclair, N. J.
†6404	-----	M. S. Crosby.	Rhinebeck, N. Y.	Sept. 30, 1921	Oct. 1, 1921	Rhinebeck, N. Y.

White-throated Sparrow—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
61214	-----	J. A. Gillespie	Glenolden, Pa	Nov. 8, 1922	Apr. 14, 1923	Glenolden, Pa.
61221	-----	do	do	Nov. 19, 1922	Apr. 18, 1923	Do.
*7511	-----	Miss Esther Heacock.	Wyncote, Pa	Dec. 31, 1916	Apr. 7, 1920	Wyncote, Pa.
*11880	-----	do	do	Jan. 19, 1920	Dec. 9, 1920	Do.
*17505	-----	do	do	Dec. 25, 1919	Feb. 27, 1920	Do.
*30089	-----	do	do	Dec. 12, 1915	Jan. 8, 1920	Do.
*44913	-----	do	do	Jan. 8, 1920	Dec. 24, 1920	Do.
*44913	-----	do	do	do	Apr. 12, 1921	Do.
*44922	-----	do	do	Jan. 14, 1920	Dec. 25, 1920	Do.
*46275	-----	do	do	Apr. 4, 1920	Dec. 14, 1920	Do.
*46275	-----	do	do	do	Mar. 19, 1922	Do.
†42251	-----	W. B. Keighton.	Swarthmore, Pa.	Mar. 6, 1923	Apr. 17, 1923	Swarthmore, Pa

Tree Sparrow: *Spizella monticola*

†67247	-----	Mrs. F. D. Hubbard	New Haven, Conn.	Jan. 30, 1923	Mar. 7, 1923	New Haven, Conn.
25562	♂	Frank Novak.	Fairfield, Conn.	Mar. 31, 1922	Jan. 8, 1923	Fairfield, Conn.
7235	-----	W. I. Lyon.	Waukegan, Ill.	Feb. 26, 1922	Nov. 11, 1922	Waukegan, Ill.
7236	-----	do	do	Feb. 27, 1922	Dec. 17, 1922	Do.
7236	-----	do	do	do	Feb. 19, 1923	Do.
7237	-----	do	do	do	Jan. 20, 1923	Do.
7239	-----	do	do	do	Dec. 31, 1922	Do.
7248	-----	do	do	Mar. 4, 1922	Dec. 5, 1922	Do.
7249	-----	do	do	do	Jan. 12, 1923	Do.
7270	-----	do	do	Mar. 22, 1922	Jan. 23, 1923	Do.
†17136	-----	do	do	Jan. 14, 1923	Jan. 24, 1923	Do.
†17139	-----	do	do	Jan. 19, 1923	Feb. 19, 1923	Do.
†17154	-----	do	do	Feb. 2, 1923	Feb. 23, 1923	Do.
†17157	-----	do	do	Feb. 4, 1923	Feb. 13, 1923	Do.
22537	-----	do	do	Apr. 15, 1922	Nov. 25, 1922	Do.
14030	♀	A. C. Bagg	Holyoke, Mass.	Feb. 17, 1922	Jan. 6, 1923	Holyoke, Mass.
22188	♂	do	do	Feb. 10, 1922	Dec. 11, 1922	Do.
22190	♀	do	do	do	do	Do.
22196	♂	do	do	Feb. 14, 1922	Dec. 4, 1922	Do.
22198	♀	do	do	Feb. 11, 1922	Dec. 18, 1922	Do.
22199	♀	do	do	do	Dec. 19, 1922	Do.
22202	♀	do	do	do	Dec. 13, 1922	Do.
†35819	-----	L. B. Fletcher	Cohasset, Mass.	Feb. 13, 1923	Feb. 14, 1923	Cohasset, Mass.
†35824	-----	do	do	Feb. 19, 1923	Feb. 28, 1923	Do.
†38483	-----	Mrs. E. A. Her- rick	Topsfield, Mass.	Jan. 18, 1923	Mar. 10, 1923	Topsfield, Mass.
†61369	-----	do	do	Jan. 24, 1923	Feb. 22, 1923	Do.
†61376	-----	do	do	Jan. 26, 1923	Mar. 5, 1923	Do.
†61381	-----	do	do	Jan. 29, 1923	Mar. 9, 1923	Do.
†61388	-----	do	do	Jan. 31, 1923	Apr. 14, 1923	Do.
33029	-----	Arthur Morley	Swampscott, Mass.	Jan. 12, 1923	Jan. 21, 1923	Danvers, Mass.
65707	-----	do	do	Jan. 17, 1922	Mar. 2, 1923	Essex, Mass.
*47044	-----	Herbert Parker.	South Lancaster, Mass.	Jan. 14, 1922	Dec. 31, 1922	South Lancaster, Mass.
6912	-----	do	do	Jan. 29, 1922	Feb. 17, 1923	Do.
6916	-----	do	do	do	Dec. 31, 1922	Do.
6919	-----	do	do	Feb. 16, 1922	Jan. 20, 1923	Do.

Tree Sparrow—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
†26233	-----	Mrs. E. V. Perkins.	Topsfield, Mass.	Jan. 7, 1923	Mar. 13, 1923	Topsfield, Mass.
†50267	-----	Mrs. A. B. Pratt.	Middleboro, Mass.	Feb. 1923	Apr. 8, 1923	Middleboro, Mass.
†50270	-----	do.....	do.....	Feb. 21, 1923	Mar. 23, 1923	Do.
†64550	-----	W. H. Ropes.	Danvers, Mass.	Dec. 30, 1922	Mar. 4, 1923	Danvers, Mass.
22107	-----	W. P. Wharton.	Groton, Mass.	Apr. 1, 1922	Feb. 25, 1923	Groton, Mass.
†39735	-----	E. C. Weeks.	Sanbornton, N. H.	Feb. 16, 1923	Mar. 27, 1923	Sanbornton, N. H.
*49269	-----	B. S. Bowditch.	Demarest, N. J.	Feb. 23, 1920	Jan. 17, 1922	Demarest, N. J.
*50020	-----	do.....	do.....	Feb. 27, 1921	Jan. 27, 1922	Do.
†6964	-----	do.....	do.....	Jan. 30, 1922	Feb. 14, 1922	Do.
6966	-----	do.....	do.....	do.....	Dec. 9, 1922	Do.
†6980	-----	do.....	do.....	Feb. 12, 1922	Mar. 3, 1922	Do.
†6993	-----	do.....	do.....	Feb. 16, 1922	Feb. 17, 1922	Do.
6996	-----	do.....	do.....	Feb. 19, 1922	Dec. 18, 1922	Do.
6996	-----	do.....	do.....	do.....	Feb. 1, 1923	Do.
*55099	-----	T. D. Carter.	Boonton, N. J.	Mar. 18, 1922	Feb. 7, 1923	Boonton, N. J.
*47684	-----	A. A. Allen.	Ithaca, N. Y.	Jan. 27, 1921	Jan. 29, 1922	Ithaca, N. Y.
*51550	-----	do.....	do.....	Jan. 17, 1921	Jan. 4, 1922	Do.
*51550	-----	do.....	do.....	do.....	Jan. 18, 1922	Do.
*16147	-----	M. S. Crosby.	Rhinebeck, N. Y.	Jan. 16, 1920	Feb. 5, 1921	Rhinebeck, N. Y.
*16147	-----	do.....	do.....	do.....	Feb. 3, 1922	Do.
*46173	-----	do.....	do.....	Feb. 24, 1920	Feb. 26, 1921	Do.
*46189	-----	do.....	do.....	Mar. 16, 1920	Feb. 5, 1921	Do.
†13687	-----	S. T. Danforth.	Ithaca, N. Y.	Nov. 19, 1922	Dec. 15, 1922	Ithaca, N. Y.
†65636	-----	R. E. Horsey.	Rochester, N. Y.	Dec. 24, 1922	Apr. 6, 1923	Rochester, N. Y.
†28631	-----	H. E. Childs.	Pawtucket, R. I.	Feb. 10, 1923	Mar. 7, 1923	Pawtucket, R. I.

Chipping Sparrow: *Spizella passerina*

*38839	-----	S. P. Baldwin.	Thomasville, Ga.	Mar. 26, 1917	Mar. 24, 1921	Thomasville, Ga.
*45408	-----	do.....	do.....	Mar. 2, 1920	Mar. 16, 1922	Do.
*45419	-----	do.....	do.....	Mar. 7, 1920	Mar. 21, 1922	Do.
*45448	-----	do.....	do.....	Mar. 10, 1920	Feb. 28, 1921	Do.
*45484	-----	do.....	do.....	Mar. 13, 1920	Mar. 27, 1921	Do.
*45489	-----	do.....	do.....	do.....	Apr. 5, 1922	Do.
*45822	-----	do.....	do.....	Mar. 14, 1920	Feb. 26, 1921	Do.
*45876	-----	do.....	do.....	Mar. 19, 1920	Mar. 19, 1921	Do.
*45881	-----	do.....	do.....	Mar. 20, 1920	Mar. 15, 1921	Do.
*45887	-----	do.....	do.....	do.....	Mar. 1, 1921	Do.
*45924	-----	do.....	do.....	Mar. 23, 1920	Mar. 3, 1921	Do.
*45924	-----	do.....	do.....	do.....	Mar. 12, 1922	Do.
*46868	-----	do.....	do.....	Feb. 21, 1921	Mar. 13, 1922	Do.
*46869	-----	do.....	do.....	Feb. 22, 1921	Mar. 22, 1922	Do.
*46876	-----	do.....	do.....	do.....	Mar. 13, 1922	Do.
*48518	-----	do.....	do.....	Feb. 25, 1921	Apr. 8, 1922	Do.
*48520	-----	do.....	do.....	do.....	Mar. 19, 1922	Do.
*48532	-----	do.....	do.....	Feb. 26, 1921	do.....	Do.
*48553	-----	do.....	do.....	Mar. 1, 1921	Mar. 25, 1922	Do.
*48570	-----	do.....	do.....	Mar. 2, 1921	Mar. 20, 1922	Do.
*48572	-----	do.....	do.....	do.....	Mar. 13, 1922	Do.
*48573	-----	do.....	do.....	do.....	Mar. 26, 1922	Do.
*48580	-----	do.....	do.....	Mar. 3, 1921	Mar. 28, 1922	Do.
*48581	-----	do.....	do.....	do.....	Mar. 13, 1922	Do.
*48584	-----	do.....	do.....	do.....	Mar. 21, 1922	Do.

Chipping Sparrow—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
*48588	-----	S. P. Baldwin	Thomasville, Ga.	Mar. 3, 1921	Mar. 30, 1922	Thomasville, Ga.
*48608	-----	do	do	Mar. 5, 1921	Mar. 20, 1922	Do.
*48636	-----	do	do	Mar. 8, 1921	Mar. 27, 1922	Do.
*48667	-----	do	do	Mar. 14, 1921	Mar. 19, 1922	Do.
*48670	-----	do	do	do	Mar. 21, 1922	Do.
*48711	-----	do	do	Mar. 19, 1921	Mar. 13, 1922	Do.
*48744	-----	do	do	Mar. 27, 1921	Mar. 22, 1922	Do.
*48748	-----	do	do	Mar. 28, 1921	Mar. 18, 1922	Do.
*48751	-----	do	do	do	Apr. 5, 1922	Do.
*48753	-----	do	do	do	Mar. 29, 1922	Do.
*48754	-----	do	do	Mar. 29, 1921	Mar. 18, 1922	Do.
22896	-----	do	do	Mar. 14, 1921	Mar. 21, 1922	Do.
†22922	-----	L. R. Talbot	do	Mar. 24, 1922	Mar. 24, 1922	Do.
22332	-----	E. P. Brown	Belfast, Me.	June 22, 1922	May 9, 1923	Belfast, Me.
22333	-----	do	do	do	May 11, 1923	Do.
28710	-----	H. D. Chadwick.	Westfield, Mass.	Aug. 10, 1922	May 27, 1923	Westfield, Mass.
26868	-----	L. B. Fletcher.	Cohasset, Mass.	June 11, 1922	May 3, 1923	Cohasset, Mass.
26388	♂	Mrs. E. A. Herrick.	Topsfield, Mass.	Apr. 25, 1922	May 21, 1923	Topsfield, Mass.
29645	-----	do	do	May 17, 1922	May 16, 1923	Do.
29646	-----	do	do	do	May 14, 1923	Do.
29650	-----	do	do	May 21, 1922	May 4, 1923	Do.
29653	-----	do	do	May 23, 1922	do	Do.
†25011	-----	L. R. Talbot	Winnepesaukee, N. H.	July 17, 1922	Sept. 7, 1922	Winnepesaukee, N. H.
21228	-----	S. P. Baldwin	Gates Mills, Ohio.	June 15, 1921	June 20, 1921	Gates Mills, Ohio.
21376	-----	do	do	Sept. 14, 1921	July 9, 1922	Do.
21377	-----	do	do	do	July 4, 1922	Do.
†26539	-----	do	do	June 25, 1922	June 25, 1922	Do.
*38643	-----	do	do	Sept 12, 1916	Sept. 25, 1920	Do.
*46829	-----	do	do	Oct. 14, 1920	July 31, 1921	Do.
†30073	-----	Fr. Damian Smith.	Manchester, N. H.	May 23, 1922	May 24, 1922	Manchester, N. H.
30074	-----	do	do	May 24, 1922	Apr. 25, 1923	Do.
*45080	-----	William Pepper.	Newtown, Pa.	May 31, 1920	May 17, 1921	Newtown, Pa.
*†48852	-----	T. D. Carter	Boonton, N. J.	May 27, 1921	June 10, 1921	Boonton, N. J.
†56152	-----	C. H. Preston	Danvers, Mass.	May 8, 1923	May 17, 1923	Danvers, Mass.
†59449	-----	Wilfrid Scott	Guelph, Ontario	June 22, 1923	June 24, 1923	Guelph, Ontario.
75051	♂	R. C. Flannigan.	Norway, Mich.	July 5, 1922	May 19, 1923	Norway, Mich.

Field Sparrow: *Spizella pusilla*

†22647	-----	W. I. Lyon	Waukegan, Ill.	Oct. 10, 1922	Oct. 14, 1922	Waukegan, Ill.
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Slate-colored Junco: *Junco hyemalis*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
25557	♂	Frank Novak	Fairfield, Conn.	Mar. 28, 1922	Apr. 1, 1923	Fairfield, Conn.
27451	♂	do	do	Apr. 19, 1922	Jan. 11, 1923	Do.
†22815		L. R. Talbot	Thomasville, Ga.	Mar. 18, 1922	Mar. 18, 1922	Thomasville, Ga.
*29120	♂	W. I. Lyon	Waukegan, Ill.	Apr. 1, 1920	Feb. 7, 1921	Waukegan, Ill.
*29120	♂	do	do	do	Jan. 15, 1922	Do.
*50598	♂	do	do	Dec. 26, 1920	Dec. 17, 1922	Do.
*52402	♂	do	do	do	Dec. 21, 1921	Do.
*52402	♂	do	do	do	Feb. 7, 1923	Do.
*52671		do	do	Oct. 7, 1921	Apr. 22, 1922	Do.
*52677		do	do	do	Apr. 9, 1922	Do.
†7110		do	do	Nov. 1, 1921	Nov. 11, 1921	Do.
†7149		do	do	Nov. 12, 1921	Dec. 14, 1921	Do.
7231		do	do	Feb. 25, 1922	Jan. 3, 1923	Do.
†7278		do	do	Mar. 25, 1922	Apr. 20, 1922	Do.
7281		do	do	Mar. 22, 1922	Dec. 24, 1922	Do.
†13013		do	do	Oct. 19, 1921	Nov. 9, 1921	Do.
†22487	♀	do	do	Apr. 12, 1922	Apr. 15, 1922	Do.
†22539		do	do	Apr. 16, 1922	Apr. 17, 1922	Do.
†22548		do	do	Apr. 17, 1922	Apr. 20, 1922	Do.
†22565		do	do	Apr. 21, 1922	Apr. 29, 1922	Do.
†22664		do	do	Nov. 6, 1922	Dec. 9, 1922	Do.
†22665		do	do	do	Nov. 28, 1922	Do.
†22666		do	do	Nov. 7, 1922	do	Do.
†22669		do	do	do	do	Do.
†32012		do	do	Nov. 20, 1922	Nov. 28, 1922	Do.
†32016		do	do	Nov. 21, 1922	do	Do.
†13364		Geo. Roberts	Lake Forest, Ill.	Apr. 12, 1922	Apr. 16, 1922	Lake Forest, Ill.
7435		Miss K. M. Hempel	Elkader, Iowa.	Dec. 17, 1921	Dec. 18, 1922	Elkader, Iowa.
†26411		B. W. Cartwright	Sturgeon Creek, Manitoba.	Oct. 15, 1922	Oct. 18, 1922	Sturgeon Creek, Manitoba.
13500	♀	E. C. Meyers	Baltimore, Md.	Feb. 18, 1922	Feb. 8, 1923	Baltimore, Md.
†24620	♂	do	do	Feb. 6, 1923	Feb. 20, 1923	Do.
†24633	♀	do	do	Feb. 8, 1923	do	Do.
†12205	♀	Mrs. L. D. Morey	Chevy Chase, Md.	Jan. 13, 1922	Jan. 27, 1922	Chevy Chase, Md.
14871	♂	Mrs. G. E. Burbank	Sandwich, Mass.	Mar. 31, 1922	May 20, 1922 ¹	Buckland, Mass.
†33776		R. B. Harding	Cohasset, Mass.	Jan. 29, 1923	Feb. 1, 1923	Cohasset, Mass.
†22140		R. B. Mackintosh	Danvers, Mass.	Jan. 7, 1923	Jan. 12, 1923	Danvers, Mass.
†35377		Arthur Morley	Swampscott, Mass.	Dec. 29, 1922	Jan. 4, 1923	Swampscott, Mass.
†63302		G. H. Priest	Brockton, Mass.	Jan. 7, 1923	Mar. 11, 1923	Brockton, Mass.
†35755		W. H. Ropes	Danvers, Mass.	Dec. 20, 1922	Jan. 10, 1923	Danvers, Mass.
†34743	♀	Miss L. M. Smith	South Sudbury, Mass.	Dec. 17, 1922	Jan. 17, 1923	South Sudbury, Mass.
†65355	♀	do	do	Jan. 10, 1923	Jan. 11, 1923	Do.
6022		S. P. Jones	Webster Groves, Mo.	Dec. 22, 1921	Jan. 3, 1923	Marshall, Ill.
12532		do	do	Feb. 2, 1922	Feb. 2, 1923	Webster Groves, Mo.
*50021		B. S. Bowditch	Demarest, N. J.	Feb. 27, 1921	Jan. 15, 1923	Demarest, N. J.
*45712		R. H. Howland	Upper Montclair, N. J.	Mar. 13, 1920	Feb. 20, 1921	Upper Montclair, N. J.
*45740		do	do	Nov. 28, 1920	Oct. 15, 1921	Do.
*47127		do	do	Nov. 14, 1920	Feb. 20, 1921	Do.
*47130		do	do	Nov. 28, 1920	Feb. 23, 1921	Do.

¹ Date approximate.

Slate-colored Junco—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
*47136	-----	R. H. Howland.	Upper Montclair, N. J.	Feb. 22, 1921	Jan. 7, 1923	Upper Montclair, N. J.
7308	-----	do.	do.	Feb. 10, 1922	Mar. 25, 1923	Do.
*45752	-----	A. A. Allen	Ithaca, N. Y.	Jan. 4, 1919	Feb. 26, 1921	Ithaca, N. Y.
*45754	-----	do.	do.	do.	Dec. 18, 1922	Do.
*51531	-----	do.	do.	Jan. 2, 1922	Mar. 7, 1923	Do.
†34792	-----	M. D. Pirnie and A. A. Allen.	do.	Feb. 19, 1923	Feb. 21, 1923	Do.
*16150	-----	M. S. Crosby.	Rhinebeck, N. Y.	Jan. 16, 1920	Feb. 27, 1921	Rhinebeck, N. Y.
*27136	-----	do.	do.	Jan. 21, 1920	Dec. 7, 1922	Do.
*27137	-----	do.	do.	do.	Jan. 23, 1922	Do.
*27137	-----	do.	do.	do.	Nov. 6, 1922	Do.
*29140	-----	do.	do.	Mar. 19, 1920	Jan. 22, 1922	Do.
*29140	-----	do.	do.	do.	Jan. 30, 1923	Do.
*29142	-----	do.	do.	Mar. 20, 1920	Jan. 27, 1922	Do.
*29142	-----	do.	do.	do.	Jan. 28, 1923	Do.
*46172	-----	do.	do.	Feb. 23, 1920	Jan. 27, 1922	Do.
*46185	-----	do.	do.	Feb. 28, 1920	Feb. 12, 1921	Do.
*46185	-----	do.	do.	do.	Dec. 5, 1921	Do.
*46195	-----	do.	do.	Mar. 18, 1920	Dec. 25, 1920	Do.
*48207	-----	do.	do.	Feb. 12, 1921	Nov. 5, 1922	Do.
*48207	-----	do.	do.	do.	Jan. 28, 1923	Do.
*†48846	-----	do.	do.	Jan. 26, 1923	Jan. 31, 1923	Do.
6465	-----	do.	do.	Dec. 23, 1921	Dec. 17, 1922	Do.
†6478	-----	do.	do.	Jan. 19, 1922	Mar. 2, 1922	Do.
†6498	-----	do.	do.	Mar. 1, 1922	Mar. 5, 1922	Do.
*50682	-----	R. O. Merri-man.	Hamilton, Ontario.	Oct. 26, 1920	Jan. 25, 1921	Hamilton, Ontario.
†61226	-----	J. A. Gillespie.	Glenolden, Pa.	Nov. 27, 1922	Mar. 7, 1923	Glenolden, Pa.
*44720	-----	I. H. Johnston	Charleston, W. Va.	Jan. 24, 1921 ²	Sept. 7, 1922	Charleston, W. Va.

Song Sparrow: *Melospiza melodia*

*39665	-----	Frank Novak.	Fairfield, Conn.	Sept. 23, 1922	Apr. 12, 1923	Fairfield, Conn.
25312	-----	do.	do.	Mar. 21, 1922	Mar. 31, 1923	Do.
25560	-----	do.	do.	Mar. 29, 1922	Apr. 11, 1923	Do.
27500	-----	do.	do.	July 14, 1922	Mar. 31, 1923	Do.
*49470	-----	Lewis Rumford.	Wilmington, Del.	Aug. 16, 1922	May 23, 1923	Wilmington, Del.
*†8591	-----	E. R. Kalmbach.	Woodridge, D. C.	Mar. 15, 1921	Apr. 1, 1921	Woodridge, D. C.
*†8594	-----	do.	do.	Mar. 22, 1921	Apr. 29, 1921	Do.
*50101	♀	W. I. Lyon	Waukegan, Ill.	May 2, 1920	Apr. 13, 1921	Waukegan, Ill.
*50101	♀	do.	do.	do.	Mar. 30, 1922	Do.
*52511	-----	do.	do.	Apr. 22, 1921	Aug. 12, 1922	Do.
*52638	-----	do.	do.	Oct. 6, 1921	Apr. 23, 1922	Do.
*53638	-----	do.	do.	Apr. 28, 1920	Apr. 25, 1921	Do.
*54334	-----	do.	do.	Mar. 20, 1921	Apr. 19, 1922	Do.
†22345	-----	E. P. Brown.	Belfast, Me.	Aug. 16, 1922	Aug. 18, 1922	Belfast, Me.
†24636	-----	E. C. Meyers	Baltimore, Md.	Feb. 10, 1923	Feb. 20, 1923	Baltimore, Md.
6313	-----	Mrs. L. D. Morey.	Chevy Chase, Md.	Oct. 14, 1921	Apr. 3, 1922	Chevy Chase, Md.

² Date approximate.

Song Sparrow—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
†27254	-----	A. C. Bagg	Holyoke, Mass.	May 9, 1922	May 12, 1922	Holyoke, Mass.
†65205	-----	do	do	Mar. 28, 1923	Mar. 29, 1923	Do.
†65208	-----	do	do	Mar. 31, 1923	Mar. 31, 1923	Do.
†22323	-----	R. L. Coffin	Amherst, Mass.	Apr. 7, 1922	Apr. 11, 1922	Amherst, Mass.
13938	-----	R. L. Elwell	Melrose Highlands, Mass.	July 15, 1922	Apr. 2, 1923	Haverhill, Mass.
11006	-----	L. B. Fletcher	Cohasset, Mass.	May 28, 1921	May 13, 1922	Cohasset, Mass.
11006	-----	do	do	do	Apr. 20, 1923	Do.
11070	-----	do	do	May 28, 1922	Apr. 26, 1923	Do.
28070	-----	do	do	July 6, 1922	Jan. 11, 1923	Do.
28070	-----	do	do	do	Feb. 28, 1923	Do.
28071	-----	do	do	do	Apr. 18, 1923	Do.
27051	-----	S y d n e y Harris	Chilmark, Mass.	June 17, 1922	Apr. 8, 1923	Chilmark, Mass.
27052	-----	do	do	May 29, 1922	Mar. 30, 1923	Do.
27053	-----	do	do	May 27, 1922	June 9, 1923	Do.
27054	-----	do	do	May 20, 1922	Apr. 26, 1923	Do.
28190	-----	do	do	Sept. 26, 1922	Apr. 14, 1923	Do.
31362	-----	do	do	Aug. 28, 1922	Apr. 29, 1923	Do.
31369	-----	do	do	Aug. 29, 1922	Mar. 31, 1923	Do.
74792	-----	do	do	July 23, 1922	Mar. 27, 1923	Do.
74793	-----	do	do	July 20, 1922	Apr. 12, 1923	Do.
75656	-----	do	do	Aug. 6, 1922	Mar. 28, 1923	Do.
75658	-----	do	do	Aug. 7, 1922	June 9, 1923	Do.
24885	-----	Mrs. E. L. Hathaway	W. Bridge-water, Mass.	July 23, 1922	Apr. 11, 1923	West Bridgewater, Mass.
24885	-----	do	do	do	Aug. 9, 1923	Do.
†52958	-----	J. D. Houghton	Chestnut Hill, Mass.	Apr. 1, 1923	June 7, 1923	Chestnut Hill, Mass.
30215	-----	Arthur Morley	Swampscott, Mass.	June 18, 1922	Mar. 31, 1923	Swampscott, Mass.
†39194	-----	W. B. Savary	E. Wareham, Mass.	Mar. 2, 1923	June 21, 1923	East Wareham, Mass.
†31080	-----	C. L. Whittle	Cohasset, Mass.	Dec. 29, 1922	Jan. 30, 1923	Cohasset, Mass.
†12029	-----	M. J. Magee	Sault Ste. Marie, Mich.	Apr. 25, 1922	Aug. 27, 1922	Sault Ste. Marie, Mich.
27273	-----	Fr. Damian Smith	Manchester, N. H.	May 9, 1922	Apr. 24, 1923	Manchester, N. H.
27276	-----	do	do	Apr. 30, 1922	Apr. 16, 1923	Do.
27287	-----	do	do	Apr. 20, 1922	May 4, 1923	Do.
30078	-----	do	do	May 16, 1922	Apr. 2, 1923	Do.
*50022	-----	B. S. Bowdish	Demarest, N. J.	Apr. 11, 1921	Aug. 14, 1921	Demarest, N. J.
*50023	♀	do	do	Apr. 26, 1921	Mar. 17, 1922	Do.
*50024	-----	do	do	do ²	July 9, 1922	Do.
*50045	-----	do	do	July 13, 1921	July 18, 1922	Do.
14757	-----	do	do	July 29, 1922	Dec. 17, 1922	Do.
*44699	-----	R. H. Howland	Upper Montclair, N. J.	Nov. 11, 1920	Oct. 27, 1921	Upper Montclair, N. J.
*44699	-----	do	do	do	Dec. 7, 1922	Do.
*45718	-----	do	do	Mar. 28, 1920	Mar. 6, 1921	Do.
*47118	-----	do	do	Aug. 8, 1920	Feb. 21, 1921	Do.
*47143	-----	do	do	Apr. 12, 1921	Mar. 23, 1922	Do.
*47143	-----	do	do	do	Mar. 23, 1923	Do.
*47150	-----	do	do	May 10, 1921	Feb. 13, 1922	Do.
*48475	-----	do	do	May 30, 1921	Mar. 19, 1922	Do.
7344	-----	do	do	Apr. 27, 1922	Mar. 24, 1923	Do.
27023	-----	do	do	June 24, 1922	Mar. 17, 1923	Do.

² Date approximate.

Song Sparrow—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
*44475	-----	A. A. Allen	Ithaca, N. Y.	— — 1919	Apr. 28, 1920	Ithaca, N. Y.
*46959	-----	do	do	Apr. 30, 1920	May 15, 1922	Do.
*47057	-----	do	do	June 30, 1920	Aug. 3, 1921	Do.
*50177	-----	do	do	Apr. 27, 1920	Mar. 13, 1921	Do.
*55019	-----	Verdi Burtch	Branchport, N. Y.	July 24, 1922	Mar. 22, 1923	Branchport, N. Y.
7069	-----	do	do	Mar. 27, 1922	July 27, 1922	Do.
17917	-----	do	do	Aug. 9, 1922	Apr. 9, 1923	Do.
*46408	-----	M. S. Crosby	Rhinebeck, N. Y.	Apr. 13, 1920	Oct. 2, 1920	Rhinebeck, N. Y.
*46479	-----	do	do	Apr. 27, 1920	Oct. 10, 1920	Do.
*46479	-----	do	do	do	May 2, 1921	Do.
*46495	-----	do	do	Sept. 27, 1920	Apr. 22, 1921	Do.
*46496	-----	do	do	do	May 1, 1921	Do.
*47201	-----	do	do	do	Apr. 25, 1921	Do.
*47202	-----	do	do	Sept. 28, 1920	July 30, 1921	Do.
*47204	-----	do	do	Oct. 2, 1920	Mar. 25, 1921	Do.
*48233	-----	do	do	Apr. 3, 1921	Mar. 25, 1922	Do.
*48241	-----	do	do	Apr. 25, 1921	Apr. 3, 1922	Do.
*48263	-----	do	do	July 27, 1921	Mar. 30, 1922	Do.
*48278	-----	do	do	Aug. 3, 1921	do	Do.
*48279	-----	do	do	Aug. 7, 1921	Mar. 31, 1922	Do.
30481	-----	R. E. Horsey	Rochester, N. Y.	May 27, 1922	Apr. 9, 1923	Rochester, N. Y.
30484	-----	do	do	July 18, 1922	Mar. 26, 1923	Do.
30485	-----	do	do	July 29, 1922	Apr. 6, 1923	Do.
*49572	-----	L. H. Snyder	Cold Spring Harbor, Long Island, N. Y.	Aug. 12, 1922	Aug. 15, 1922	Cold Spring Harbor, Long Island, N. Y.
*45348	-----	S. P. Baldwin	Gates Mills, Ohio.	July 3, 1919	May 17, 1921	Gates Mills, Ohio.
*45359	-----	do	do	July 18, 1919	July 31, 1920	Do.
*45399	-----	do	do	Oct. 7, 1919	June 4, 1920	Do.
*45989	-----	do	do	July 5, 1920	July 7, 1921	Do.
*46044	-----	do	do	July 25, 1920	May 14, 1921	Do.
*46047	-----	do	do	do	June 15, 1921	Do.
*46731	-----	do	do	Sept. 18, 1920	June 4, 1921	Do.
*48774	-----	do	do	May 24, 1921	July 18, 1922	Do.
6837	-----	do	do	Oct. 29, 1921	Sept. 14, 1922	Do.
†21261	-----	do	do	June 18, 1921	July 3, 1921	Do.
21277	-----	do	do	July 4, 1921	June 8, 1922	Do.
21282	-----	do	do	July 5, 1920	July 7, 1921	Do.
21282	-----	do	do	do	Sept. 8, 1922	Do.
21306	-----	do	do	July 16, 1921	July 20, 1922	Do.
21309	-----	do	do	July 17, 1921	July 2, 1922	Do.
21310	-----	do	do	do	July 6, 1922	Do.
21347	-----	do	do	July 28, 1921	July 9, 1922	Do.
26562	-----	do	do	July 6, 1922	June 10, 1923	Do.
†26614	-----	do	do	July 15, 1922	July 16, 1922	Do.
26617	-----	do	do	July 16, 1922	June 16, 1923	Do.
†6351	-----	A. B. Williams	Willoughby, Ohio.	Aug. 22, 1921	Sept. 4, 1921	Willoughby, Ohio.
†61233	-----	J. A. Gillespie	Glenolden, Pa.	Dec. 23, 1922	Jan. 25, 1923	Glenolden, Pa.
†61243	-----	do	do	Jan. 18, 1923	Mar. 7, 1923	Do.
†61245	-----	do	do	Jan. 26, 1923	do	Do.
*46257	-----	Miss Esther Heacock	Wyncote, Pa.	Dec. 29, 1920	Apr. 23, 1922	Wyncote, Pa.
*50151	-----	William Pepper	Newtown Square, Pa.	Oct. 26, 1920	June 8, 1921	Newtown Square, Pa.

Song Sparrow—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
†42280	-----	R. F. Marshall	Barrington, R. I.	Mar. 7, 1923	Mar. 30, 1923	Barrington, R. I.
*48937	-----	J. A. Sinclair	Enosburg Falls, Vt.	Sept. 17, 1921	Apr. 1, 1922	Enosburg Falls, Vt.
*†27174	-----	I. H. Johnston	Charleston, W. Va.	Nov. 27, 1922	Dec. 27, 1922	Charleston, W. Va.
*47479	-----	do.....	do.....	June 27, 1922	Feb. 18, 1923	Do.

Fox Sparrow: *Passerella iliaca*

*†54400	-----	W. I. Lyon	Waukegan, Ill.	Nov. 22, 1921	Dec. 4, 1921	Waukegan, Ill.
†13956	-----	W. P. Wharton.	Groton, Mass.	Apr. 1, 1922	Apr. 3, 1922 ²	Groton, Mass.

Towhee: *Pipilo erythrophthalmus*

*†52306	♂	S. P. Baldwin	Thomasville, Ga.	Mar. 3, 1921	Mar. 5, 1921	Thomasville, Ga.
28187	♂	Sydney Harris	Chilmark, Mass.	July 21, 1922	May 16, 1923	Chilmark, Mass.
†106040	♂	do.....	do.....	Sept. 18, 1922	Nov. 7, 1922 ²	Do.
†16368	♂	B. S. Bowdish	Demarest, N. J.	Dec. 22, 1921	Jan. 21, 1923	Demarest, N. J.
†42002	♂	C. L. Morse	Montclair, N. J.	May 5, 1923	May 19, 1923	Montclair, N. J.

Anthony Towhee: *Pipilo crissalis senicula*

†12725	-----	J. E. Law	Pasadena, Calif.	Oct. 27, 1922	Dec. 21, 1922	Pasadena, Calif.
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Cardinal: *Cardinalis cardinalis*

*50390	-----	E. R. Kalmbach.	Woodridge, D. C.	July 24, 1921	May 10, 1922	Woodridge, D. C.
*55198	♀	Miss M. J. Pellew.	Washington, D. C.	Oct. 18, 1920	Feb. 25, 1921	Washington, D. C.
*55199	♀	do.....	do.....	do.....	Feb. 21, 1921	Do.
*32197	♀	S. P. Baldwin	Thomasville, Ga.	Mar. 20, 1917	Feb. 13, 1920	Thomasville, Ga.
*41898	♀	do.....	do.....	Mar. 12, 1917	Mar. 28, 1921	Do.
*53077	♂	do.....	do.....	Feb. 16, 1920	Mar. 22, 1921	Do.
*53094	♂	do.....	do.....	Mar. 13, 1920	Mar. 19, 1921	Do.
*55205	♀	do.....	do.....	Feb. 22, 1921	Apr. 1, 1922	Do.
*55208	♀	do.....	do.....	Feb. 24, 1921	Apr. 2, 1922	Do.
*55213	♂	do.....	do.....	Mar. 4, 1921	Mar. 21, 1922	Do.
*55213	♂	do.....	do.....	do.....	Apr. 3, 1922	Do.
*55228	♀	do.....	do.....	Mar. 28, 1921	Mar. 22, 1922	Do.
16518	♂	Miss K. M. Hempel.	Elkader, Iowa	May 3, 1922	May 7, 1923	Elkader, Iowa.
12215	♂	Mrs. L. D. Morey.	Chevy Chase, Md.	Jan. 26, 1922	Jan. 7, 1923	Chevy Chase, Md
†28208	♂	J. A. Laughlin	Marshall, Mo.	Nov. 28, 1922	Apr. 8, 1923	Marshall, Mo

² Date approximate.

Cardinal—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
19925		A. F. and E. A. Satterthwait.	Webster Groves, Mo.	May 23, 1922	Feb. 11, 1923	Webster Groves, Mo.
15862	♀	Mrs. M. H. Wegener.	do	Dec. 26, 1921	Feb. 4, 1923	Do.
*†11862	♀	Miss Esther Heacock.	Wyncote, Pa.	Dec. 25, 1919	Jan. 18, 1920	Wyncote, Pa.
*†19373		do	do	do	do	Do.

Rose-breasted Grosbeak: *Hedymeles ludoviciana*

107030		W. I. Lyon	Waukegan, Ill.	May 7, 1923	June 3, 1923	Lake Forest, Ill.
*49510	♂	Geo. Roberts	Lake Forest, Ill.	May 25, 1919	May 2, 1920	Do.
*49510	♂	do	do	do	May 4, 1923	Do.

Purple Martin: *Progne subis*

†15154	♀	D. H. Boyd	Hobart, Ind.	July 27, 1921	July 28, 1921	Hobart, Ind.
†69870		Miss K. M. Hempel.	Elkader, Iowa	June 26, 1923	June 27, 1923	Elkader, Iowa.
†45884		F. W. Rapp	Vicksburg, Mich.	July 19, 1923	July 31, 1923	Vicksburg, Mich.
†45903		do	do	do	July 20, 1923	Do.
†45936		do	do	July 10, 1923	do	Do.
†104232		do	do	June 25, 1922	Sept. 29, 1922	Do.
†18999		B. H. Warren	West Chester, Pa.	July 16, 1921	July 16, 1921	West Chester, Pa.

Cliff Swallow: *Petrochelidon lunifrons*

†74729		H. E. Childs	Sweden, Me.	July 18, 1922	Aug. 16, 1922	Sweden, Me.
†74730		do	do	do	do	Do.
†74731		do	do	do	do	Do.
†75842		do	do	do	do	Do.
†75857		do	do	do	do	Do.

Barn Swallow: *Hirundo erythrogastra*

†56925		Miss L. M. Smith.	South Sudbury, Mass.	May 7, 1923	May 15, 1923 ¹	Wayland, Mass.
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Tree Swallow: *Iridoprocne bicolor*

11646		P. F. Foran	Ottawa, Ontario	June 19, 1922	May 28, 1923	Ottawa, Ontario.
11652		do	do	do	June 13, 1923	Do.
†30117		H. E. Childs	Smithfield, R. I.	June 15, 1922	Aug. 4, 1922	Smithfield, R. I.
†30127		do	do	Aug. 4, 1922	Aug. 5, 1922 ²	Do.

¹ Date approximate.

Cedar Waxwing: *Bombycilla cedrorum*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
66322	-----	W. I. Lyon	Waukegan, Ill.	Mar. 29, 1923	Apr. 10, 1923	Racine, Wis.
†69767	-----	S. T. Danforth	Squirrel Island, Me.	Aug. 1, 1923	Aug. 2, 1923	Squirrel Island, Me.
†11632	-----	P. F. Foran	Ottawa, Ontario	July 20, 1921	July 20, 1921	Ottawa, Ontario.
†16616	-----	Miss I. A. Howe.	St. Johnsbury, Vt.	July 19, 1922	July 21, 1922	St. Johnsbury, Vt.

Myrtle Warbler: *Dendroica coronata*

*27290	-----	S. P. Baldwin	Thomasville, Ga.	Feb. 28, 1917	Mar. 7, 1920	Thomasville, Ga.
*27290	-----	do	do	do	Mar. 1, 1921	Do.
*27440	-----	do	do	Mar. 1, 1917	Mar. 19, 1920	Do.
*45433	-----	do	do	Mar. 8, 1920	Feb. 21, 1921	Do.
*45478	-----	do	do	Mar. 12, 1920	Feb. 22, 1921	Do.
*45493	-----	do	do	Mar. 13, 1920	Feb. 21, 1921	Do.
*48528	-----	do	do	Feb. 26, 1921	Mar. 21, 1922	Do.

Bay-breasted Warbler: *Dendroica castanea*

†74563	-----	W. Taylor A.	Unity, Me.	July 20, 1922	July 20, 1922	Unity, Me.
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Black-poll Warbler: *Dendroica striata*

†7917	-----	R. W. Tufts	Seal Island, Nova Scotia.	June 23, 1922	June 30, 1922	Seal Island, Nova Scotia.
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Black-throated Green Warbler: *Dendroica virens*

†35795	-----	Miss C. J. Stanwood.	Ellsworth, Me.	July 3, 1923	July 3, 1923	Ellsworth, Me.
†35800	-----	do	do	do	do	Do.

Ovenbird: *Seiurus aurocapillus*

†75140	-----	S. E. Perkins	Indianapolis, Ind.	Sept. 15, 1922	Sept. 30, 1922	Indianapolis, Ind.
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Mockingbird: *Mimus polyglottos*

*53086	-----	S. P. Baldwin	Thomasville, Ga.	Feb. 19, 1920	Feb. 22, 1921	Thomasville, Ga.
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Catbird: *Dumetella carolinensis*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
*54302	♂	W. I. Lyon	Waukegan, Ill.	June 20, 1920	June 21, 1922	Waukegan, Ill.
*54353		do	do	May 10, 1921	May 8, 1922	Do.
*54353		do	do	do	June 2, 1923	Do.
†68968		Earl Brooks	Noblesville, Ind.	June 14, 1923	July 13, 1923	½ mile from Noblesville, Ind.
†110958		do	do	May 1, 1923	May 7, 1923	Noblesville, Ind.
*54898		Miss K. M. Hempel	Elkader, Iowa	June 12, 1921	May 18, 1922	Elkader, Iowa.
*54898		do	do	do	May 17, 1923	Do.
*54899		do	do	June 9, 1921	May 16, 1923	Do.
*55003		do	do	June 12, 1921	June 18, 1922	Do.
15788		do	do	May 27, 1922	June 29, 1923	Do.
15796		do	do	June 12, 1922	June 15, 1923	Do.
16517		do	do	May 12, 1922	May 18, 1923	Do.
28943		do	do	July 7, 1922	May 10, 1923	Do.
11493		Mrs. B. P. Reed	Lawrence, Kans	May 14, 1922	May 25, 1923	Lawrence, Kans.
†25846		Mrs. L. D. Morey	Chevy Chase, Md.	May 13, 1922	May 14, 1922	Chevy Chase, Md.
16352	♂	B. S. Bowditch	Demarest, N. J.	June 26, 1922	May 9, 1923	Demarest, N. J.
*50372		R. H. Howland	Upper Montclair, N. J.	May 9, 1922	May 11, 1923	Upper Montclair, N. J.
*53471		do	do	May 15, 1920	July 16, 1922	Do.
*53471		do	do	do	May 25, 1923	Do.
29199		R. E. Horsey	Rochester, N. Y.	July 30, 1922	May 8, 1923	Rochester, N. Y.
*29465		S. P. Baldwin	Gates Mills, Ohio.	June 22, 1920	May 15, 1921	Gates Mills, Ohio.
*53034		do	do	May 15, 1919	May 19, 1921	Do.
*53913		do	do	June 4, 1920	May 15, 1921	Do.
*53913		do	do	do	July 15, 1922	Do.
*53823		R. D. Book	Corning, Ohio	June 4, 1922	June 9, 1922	Corning, Ohio.
*53149		William Pepper	Newtown Square, Pa.	May 9, 1920	May 29, 1921	Newtown Square, Pa.
*54179		do	do	June 12, 1921	June 17, 1921	Do.
*54189		do	do	June 18, 1921	June 25, 1921	Do.
*53153		do	do	May 15, 1920	May 27, 1921	Do.
*53165		do	do	May 30, 1920	May 28, 1921	Do.

 Brown Thrasher: *Toxostoma rufum*

*19247		S. P. Baldwin	Thomasville, Ga.	Feb. 27, 1915	Mar. 4, 1916	Thomasville, Ga.
*19247		do	do	do	Mar. 11, 1917	Do.
*19247		do	do	do	Feb. 16, 1920	Do.
*19247		do	do	do	Mar. 28, 1922	Do. ¹⁶
*40796		do	do	1917	Mar. 16, 1920	Do.
*53085		do	do	Feb. 19, 1920	Mar. 22, 1922	Do.
*53092		do	do	Feb. 29, 1920	Mar. 29, 1921	Do.
*53092		do	do	do	Apr. 6, 1922	Do.
*53093		do	do	Mar. 10, 1920	Feb. 23, 1921	Do.
*55217		do	do	Mar. 16, 1921	Mar. 22, 1922	Do.
*55227		do	do	Mar. 26, 1921	Mar. 28, 1922	Do.
*57633	♀	W. I. Lyon	Waukegan, Ill.	June 23, 1920	Apr. 24, 1921	Waukegan, Ill.
*57642	♀	do	do	June 27, 1920	May 21, 1921	Do.
*57642	♀	do	do	do	May 21, 1922	Do.

¹⁶ Band broke and was replaced with A. B. B. A. No. 57742.

Brown Thrasher—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
†8704	-----	W. I. Lyon	Waukegan, Ill.	Aug. 6, 1922	Sept. 11, 1922	Waukegan, Ill.
15212	-----	Mrs. B. P. Reed	Lawrence, Kans.	June 13, 1921	June 17, 1921	Lawrence, Kans.
15224	-----	..do.	..do.	July 2, 1921	July 2, 1922	Do.
15229	-----	..do.	..do.	July 5, 1921	May 16, 1922	Do.
16304	-----	Mrs. L.D. Morey	Chevy Chase, Md.	Apr. 24, 1922	Sept. 14, 1922	Chevy Chase, Md.
*57813	-----	B. S. Bowdish	Demarest, N. J.	July 22, 1922	July 22, 1923	Demarest, N. J.
*42093	-----	R. H. Howland	Upper Montclair, N. J.	May 28, 1921	May 3, 1923	Upper Montclair, N. J.
19324	-----	..do.	..do.	May 11, 1922	May 5, 1923	Do.
*53035	-----	S. P. Baldwin	Gates Mills, Ohio.	May 16, 1917	June 15, 1920	Gates Mills, Ohio.
*53038	-----	..do.	..do.	June 10, 1919	July 20, 1920	Do.
*53050	-----	..do.	..do.	June 28, 1919	Mar. 25, 1922	Near Selma, Ala.
*53925	-----	..do.	..do.	July 4, 1920	May 15, 1921	Gates Mills, Ohio.
*†55502	-----	O. L. Mitchell	Cuyahoga Falls, Ohio.	May 5, 1921	May 15, 1921	Cuyahoga Falls, Ohio.
*53151	-----	William Pepper	Newtown Square, Pa.	May 14, 1920	June 1, 1921	Newtown Square, Pa.
*53152	-----	..do.	..do.	May 15, 1920	June 24, 1921	Do.

Carolina Wren: *Thryothorus ludovicianus*

†34780	-----	A. D. Moore	South Haven, Mich.	Nov. 27, 1922	Jan. 13, 1923	South Haven, Mich.
†58391	-----	Mrs. A. R. Purvis.	Charleston, W. Va.	June 9, 1923	June 10, 1923	Charleston, W. Va.
†58393	-----	..do.	..do.	..do.	..do.	Do.

House Wren: *Troglodytes aedon*

21042	-----	W. I. Lyon	Waukegan, Ill.	June 23, 1921	June 9, 1922 ²	Wilmette, Ill.
†38778	-----	Mrs. F. L. Battell.	Ames, Iowa.	May 3, 1923	June 17, 1923	Ames, Iowa.
*†47831	-----	Mrs. B. P. Reed	Lawrence, Kans.	June 12, 1921	June 19, 1921	Lawrence, Kans.
7027	♀	J. Van Tyne	Ann Arbor, Mich.	May 23, 1922	June 8, 1923	Ann Arbor, Mich.
*48478	♂	R. H. Howland	Upper Montclair, N. J.	June 19, 1921	Aug. 6, 1922	Upper Montclair, N. J.
*27062	-----	A. A. Allen	Ithaca, N. Y.	July 14, 1920	June 6, 1921	Ithaca, N. Y.
*45303	-----	S. P. Baldwin	Gates Mills, Ohio.	June 17, 1919	June 17, 1920	Gates Mills, Ohio.
*45303	-----	..do.	..do.	..do.	June 6, 1922	Do.
*45325	-----	..do.	..do.	—, 1919	July 7, 1920	Do.
*45335	♂	..do.	..do.	June 24, 1919	June 15, 1920	Do.
*45335	♂	..do.	..do.	..do.	June 14, 1921	Do.
*45335	♂	..do.	..do.	..do.	June 7, 1922	Do.
*45342	♂	..do.	..do.	June 26, 1919	June 17, 1920	Do.
*45342	♂	..do.	..do.	..do.	June 2, 1921	Do.
*45342	♂	..do.	..do.	..do.	June 14, 1922	Do.
*45349	-----	..do.	..do.	July 4, 1919	July 24, 1920	Do.
*45963	-----	..do.	..do.	June 17, 1920	June 14, 1921	Do.
*45968	-----	..do.	..do.	June 22, 1920	July 13, 1921	Do.

² Date approximate.

House Wren—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
*46006	-----	S. P. Baldwin	Gates Mills, Ohio	July 13, 1920	June 4, 1921	Gates Mills, Ohio.
*48775	♂	do	do	May 25, 1921	June 14, 1922	Do.
*48785	♂	do	do	June 2, 1921	June 19, 1922	Do.
*48785	♂	do	do	do	June 24, 1923	Do.
21212	-----	do	do	June 7, 1921	June 13, 1922	Do.
21212	-----	do	do	do	June 10, 1923	Do.
21231	♂	do	do	June 16, 1921	June 12, 1922	Do.
21264	♂	do	do	June 25, 1921	June 8, 1922	Do.
22995	♂	do	do	June 7, 1922	Apr. 24, 1923	Do.
†26507	-----	do	do	June 13, 1922	June 13, 1922	Do.
26533	-----	do	do	June 21, 1922	June 30, 1923 ²	Do.
26546	♂	do	do	June 29, 1922	June 28, 1923	Do.
26600	♂	do	do	July 13, 1922	June 16, 1923	Do.
26601	♂	do	do	do	June 10, 1923	Do.
21128	-----	H. F. Cant	Galt, Ontario	Aug. 6, 1921	July 6, 1922	Galt, Ontario.
*45081	-----	William Pepper	Newtown Square, Pa.	June 11, 1920	Apr. 24, 1921	Newtown Square, Pa.
*45090	-----	do	do	July 17, 1920	May 14, 1921	Do.
*46916	-----	do	do	June 17, 1921	June 17, 1923	Do.

White-breasted Nuthatch: *Sitta carolinensis*

*49504	-----	George Roberts	Lake Forest, Ill.	Dec. 28, 1921	Dec. 20, 1922	Lake Forest, Ill.
*47553	-----	Miss K. M. Hempel	Elkader, Iowa	Jan. 23, 1921	Mar. 13, 1922	Elkader, Iowa.
7434	-----	do	do	Dec. 21, 1921	Nov. 18, 1922	Do.
7434	-----	do	do	do	Jan. 22, 1923	Do.
7434	-----	do	do	do	May 12, 1923	Do.
7441	-----	do	do	Jan. 17, 1922	Nov. 20, 1922	Do.
†75635	-----	do	do	Dec. 7, 1922	Jan. 12, 1923	Do.
75641	-----	do	do	Nov. 17, 1922	June 13, 1923	Do.
75641	-----	do	do	do	Nov. 5, 1923	Do.
†21522	-----	Mrs. B. P. Reed	Lawrence, Kans.	Oct. 21, 1921	Nov. 17, 1921	Lawrence, Kans.
*47934	-----	J. Van Tyne	Ann Arbor, Mich.	Oct. 16, 1921	Jan. 1, 1923	Ann Arbor, Mich.
*29145	-----	M. S. Crosby	Rhinebeck, N. Y.	Mar. 20, 1920	Oct. 30, 1920	Rhinebeck, N. Y.
*29145	-----	do	do	do	Jan. 23, 1921	Do.
*46416	-----	do	do	Apr. 14, 1920	do	Do.
*46416	-----	do	do	do	Oct. 16, 1921	Do.
*46616	-----	do	do	do	Nov. 4, 1922	Do.
*46417	-----	do	do	do	Mar. 13, 1921	Do.
*48201	-----	do	do	Jan. 23, 1921	Jan. 20, 1922	Do.
†6463	-----	do	do	Dec. 9, 1921	Dec. 22, 1921	Do.
†6493	-----	do	do	Mar. 5, 1922	Apr. 10, 1922	Do.

Red-breasted Nuthatch: *Sitta canadensis*

*44295	-----	George Roberts	Lake Forest, Ill.	Nov. 13, 1921	Mar. 22, 1922	Lake Forest, Ill.
*44299	-----	do	do	Nov. 21, 1921	do	Do.

² Date approximate.

Tufted Titmouse: *Baeolophus bicolor*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
12536	-----	S. P. Jones....	Webster Groves, Mo.	Nov. 27, 1921	Jan. 6, 1923	Webster Groves, Mo.
12539	-----	do.....	do.....	Dec. 5, 1921	do.....	Do.
30429	-----	Johnson Neff..	Marionville, Mo.	June 1, 1922	Dec. 22, 1922	Marionville, Mo.
21975	-----	A. F. and E. A. Satterthwait.	Webster Groves, Mo.	Jan. 22, 1922	Nov. 19, 1922	Webster Groves, Mo.

Chickadee: *Penthestes atricapillus*

7189	-----	W. I. Lyon....	Waukegan, Ill.	Nov. 24, 1921	Jan. 1, 1922	Waukegan, Ill.
†7225	-----	do.....	do.....	Feb. 1, 1922	Feb. 22, 1922	Do.
*44292	-----	George Roberts.	Lake Forest, Ill.	Nov. 20, 1921	Mar. 21, 1922	Lake Forest, Ill.
*47551	-----	Miss K. M. Hempel.	Elkader, Iowa	Dec. 24, 1920	Oct. 14, 1921	Elkader, Iowa.
*47551	-----	do.....	do.....	do.....	Nov. 17, 1922	Do.
*47556	-----	do.....	do.....	Feb. 2, 1921	Feb. 28, 1922	Do.
*47557	-----	do.....	do.....	Feb. 8, 1921	Nov. 5, 1921	Do.
*47557	-----	do.....	do.....	do.....	Nov. 19, 1922	Do.
*48440	-----	do.....	do.....	Apr. 26, 1921	Dec. 2, 1921	Do.
7442	-----	do.....	do.....	Jan. 16, 1922	Nov. 22, 1922	Do.
25248	-----	Mrs. G. E. Burbank.	Sandwich, Mass.	Mar. 31, 1922	Dec. 6, 1922	Sandwich, Mass.
25249	-----	do.....	do.....	Apr. 2, 1922	Dec. 5, 1922	Do.
25250	-----	do.....	do.....	do.....	Dec. 6, 1922	Do.
*47940	-----	J. Van Tyne....	Ann Arbor, Mich.	Dec. 20, 1920	Dec. 23, 1922	Ann Arbor, Mich.
*47944	-----	do.....	do.....	Dec. 18, 1920	Dec. 27, 1921	Do.
*47944	-----	do.....	do.....	do.....	Mar. 3, 1922	Do.
7012	-----	do.....	do.....	Dec. 13, 1921	Oct. 26, 1922	Do.
7014	-----	do.....	do.....	Dec. 20, 1921	Dec. 28, 1922	Do.
7018	-----	do.....	do.....	Dec. 27, 1921	Dec. 24, 1922	Do.
*50640	-----	A. A. Allen....	Ithaca, N. Y.	Jan. 4, 1922	Jan. 20, 1923	Ithaca, N. Y.
*51542	-----	do.....	do.....	Mar. 7, 1921	Jan. 8, 1922	Do.
*51542	-----	do.....	do.....	do.....	Dec. 21, 1922	Do.
*27142	-----	M. S. Crosby..	Rhinebeck, N. Y.	Jan. 22, 1920	Feb. 12, 1921	Rhinebeck, N. Y.
*29138	-----	do.....	do.....	Mar. 18, 1920	Feb. 26, 1921	Do.
*29150	-----	do.....	do.....	Mar. 22, 1920	Oct. 14, 1921	Do.
*46174	-----	do.....	do.....	Feb. 24, 1920	Feb. 26, 1921	Do.
*46192	-----	do.....	do.....	Mar. 16, 1920	Jan. 9, 1921	Do.
*46192	-----	do.....	do.....	do.....	Jan. 20, 1921	Do.
*46193	-----	do.....	do.....	Mar. 17, 1920	Jan. 8, 1921	Do.
*46193	-----	do.....	do.....	do.....	Nov. 25, 1921	Do.
*46199	-----	do.....	do.....	Mar. 18, 1920	Feb. 12, 1921	Do.
*46199	-----	do.....	do.....	do.....	Jan. 23, 1922	Do.
*47270	-----	do.....	do.....	Dec. 19, 1920	Nov. 25, 1921	Do.
6460	-----	do.....	do.....	Dec. 1, 1921	Nov. 19, 1922	Do.
†6490	-----	do.....	do.....	Mar. 4, 1922	Mar. 8, 1922	Do.
*44723	-----	I. H. Johnston.	Charleston, W. Va.	Feb. 13, 1921	Jan. 31, 1923	Charleston, W. Va.
*47460	-----	do.....	do.....	Feb. 26, 1921	Feb. 7, 1923	Do.

Carolina Chickadee: *Penthestes carolinensis*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
6024	-----	S. P. Jones....	Webster Groves, Mo.	Dec. 23, 1921	Dec. 31, 1922	Webster Groves, Mo.
†21956	-----	A. F. and E. A. Satterthwait.	do.	June 18, 1922	June 19, 1922	Do.
†21974	-----	do.	do.	Dec. 4, 1921	Apr. 16, 1922	Do.

 Hermit Thrush: *Hylocichla guttata pallasi*

*16246	-----	S. B. Baldwin.	Thomasville, Ga.	Feb. 13, 1917	Feb. 23, 1920	Thomasville, Ga.
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 Robin: *Planesticus migratorius*

103020	♂	W. W. Arnold.	Colorado Springs, Colo.	Oct. 5, 1922	Mar. 5, 1923	Colorado Springs, Colo.
15398	-----	Miss A. B. Copeland.	Grand Junction, Colo.	July 5, 1922	Oct. 22, 1922	Santa Fe, N. Mex. (35 mi. N.).
*33519	-----	Lewis Rutherford.	Wilmington, Del.	July 8, 1917	May 14, 1922 ²	Wilmington, Del.
†103837	-----	do.	do.	Mar. 31, 1923	June 7, 1923	Do.
*20936	♀	W. I. Lyon....	Waukegan, Ill.	Apr. 4, 1920	Mar. 28, 1921	Waukegan, Ill.
*42061	♂	do.	do.	Apr. 7, 1920	Apr. 1, 1921	Do.
*42065	♂	do.	do.	Apr. 22, 1920	Dec. —, 1920	Corinth, Miss. (8 mi. W.)
*42790	-----	do.	do.	May 17, 1918	Apr. 6, 1920	Waukegan, Ill.
*57617	♀	do.	do.	June 18, 1920	Mar. 31, 1921	Do.
18030	♀	do.	do.	May 10, 1921	Apr. 16, 1922	Do.
18030	♀	do.	do.	do.	May 23, 1922	Do.
18043	-----	do.	do.	June 7, 1921	Apr. 12, 1922	Do.
18337	♂	do.	do.	Mar. 30, 1921	Mar. 17, 1922	Do.
18342	-----	do.	do.	Apr. 20, 1921	Mar. 28, 1922	Do.
*57603	-----	George Roberts.	Lake Forest, Ill.	Apr. 16, 1921	June 5, 1922	Lake Forest, Ill.
*57603	-----	do.	do.	do.	May 3, 1923	Do.
16468	-----	do.	do.	May 5, 1922	Apr. 15, 1923	Do.
†110956	-----	Earl Brooks.	Noblesville, Ind.	May 22, 1923	May 23, 1923	Noblesville, Ind.
13795	-----	S. E. Perkins.	Indianapolis, Ind.	Apr. 29, 1922	Mar. 24, 1923	Indianapolis, Ind.
29151	-----	do.	do.	Sept. 29, 1922	Mar. 29, 1923	Do.
30847	-----	do.	do.	Aug. 14, 1922	Apr. 24, 1923	Do.
†29823	-----	J. P. Jones.	Perry, Iowa.	May 22, 1922	May 22, 1922	Perry, Iowa.
15302	♂	Dayton Stoner	Iowa City, Iowa.	Mar. 30, 1922	Apr. 10, 1923	Iowa City, Iowa.
*†56204	-----	Mrs. B. P. Reed.	Lawrence, Kans.	May 14, 1921	May 17, 1921	Lawrence, Kans.
15239	-----	do.	do.	July 11, 1921	Apr. 28, 1922	Do.
15239	-----	do.	do.	do.	Mar. 18, 1923	Do.
15246	-----	do.	do.	June 6, 1922	Mar. 18, 1923	Do.
†15252	-----	do.	do.	July 5, 1922	July 28, 1922	Do.
103884	-----	do.	do.	June 11, 1922	Mar. 11, 1923	Do.
†8993	-----	E. H. Perkins.	Unity, Me.	July 17, 1922	Aug. 6, 1922	Unity, Me.
†16966	-----	R. L. Coffin.	Amherst, Mass.	Apr. 2, 1922	Apr. 17, 1922	Amherst, Mass.
23227	-----	R. B. Mackintosh.	Danvers, Mass.	June 12, 1922	May 1, 1923 ²	Baltimore, Md.
†70514	-----	Mrs. A. B. Pratt.	Middleboro, Mass.	Apr. 27, 1923	Apr. 27, 1923	Middleboro, Mass.

² Date approximate.

Robin—Continued

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
17203	-----	E. U. Ufford..	Auburndale, Mass.	June 6, 1922	Apr. 19, 1923	Auburndale, Mass.
†10050	-----	W. C. Wheeler	East Walpole, Mass.	July 3, 1923	July 8, 1923	East Walpole, Mass.
†16218	-----	F. W. Rapp...	Vicksburg, Mich.	Aug. 9, 1921	Aug. 19, 1921	Vicksburg, Mich.
*57921	-----	Dayton Stoner	Douglas Lake, Mich.	July 21, 1920	Jan. 21, 1921	McLain, Miss.
*56163	-----	J. Van Tyne..	Ann Arbor, Mich.	May 16, 1922	Apr. 18, 1923	Ann Arbor, Mich.
16021	-----	A. S. Warthin..	do.....	Apr. 4, 1922	Mar. 31, 1923	Do.
†48554	-----	do.....	do.....	Apr. 24, 1923	June 2, 1923	Do.
8919	-----	S. P. Jones....	Webster Groves, Mo.	Aug. 23, 1921	June 24, 1922	Webster Groves, Mo.
53328	-----	Miss. E. F. Bennett.	Meriden, N. H..	June 2, 1920	Dec. 15, 1921	Atlantic, N. C.
*†55057	-----	T. D. Carter..	Boonton, N. J..	May 11, 1921	May 19, 1921	Boonton, N. J.
*53469	♂	R. H. Howland.	Upper Montclair, N. J.	May 2, 1920	May 8, 1921	Upper Montclair, N. J.
15653	-----	do.....	do.....	Apr. 9, 1922	Apr. 8, 1923	Do.
15655	-----	do.....	do.....	Apr. 30, 1922	Mar. 22, 1923	Do.
15656	-----	do.....	do.....	do.....	Apr. 22, 1923	Do.
15661	-----	do.....	do.....	July 16, 1922	Apr. 15, 1923	Do.
†46556	-----	C. L. Morse...	Montclair, N. J.	Mar. 20, 1923	May 3, 1923	Montclair, N. J.
*†55014	-----	Verdi Burtch.	Branchport, N. Y.	May 19, 1922	May 29, 1922	Branchport, N. Y.
28747	♂	R. E. Horsey..	Rochester, N. Y.	May 16, 1922	Mar. 19, 1923	Rochester N. Y.
†103516	-----	do.....	do.....	July 10, 1922	Aug. 20, 1922	Do.
†108150	-----	do.....	do.....	Apr. 26, 1923	May 12, 1923	Do.
†108158	-----	do.....	do.....	June 5, 1923	June 9, 1923	Do.
†60466	-----	C. H. Watson...	Andover, N. Y..	July 2, 1923	July 3, 1923	Andover, N. Y.
†106914	-----	Miss. M. A. Boggs.	Waynesville, N. C.	June 19, 1923	June 20, 1923	Waynesville, N. C.
†13591	-----	R. W. Tufts...	Wolfville, Nova Scotia.	June 11, 1922	June 23, 1922	Wolfville, Nova Scotia.
†104491	-----	do.....	do.....	Oct. 2, 1922	Nov. 6, 1922	Do.
17546	♂	R. H. Smith...	Kent, Ohio.....	July 16, 1922	Mar. 28, 1923	Kent, Ohio.
†23711	-----	do.....	do.....	June 24, 1922	June 25, 1922	Do.
†111480	-----	do.....	do.....	June 27, 1923	July 2, 1923	Do.
†111490	-----	do.....	do.....	July 14, 1923	July 14, 1923	Do.
15195	♀	H. F. Cant....	Galt, Ontario...	May 24, 1922	Apr. 10, 1923	Galt, Ontario.
†15196	-----	do.....	do.....	May 10, 1922	May 27, 1922	Do.
†16102	-----	P. F. Foran...	Ottawa, Ontario	June 7, 1922	July 1, 1922	Ottawa, Ontario
†16114	-----	do.....	do.....	May 26, 1923	Aug. 10, 1923 ²	Do.
†16115	-----	do.....	do.....	do.....	June 14, 1923 ²	Do.
104127	♀	Hoyes Lloyd...	do.....	July 1, 1922	Apr. 26, 1923	Do.
†104146	-----	do.....	do.....	July 31, 1922	Aug. 1, 1922	Do.
†109724	-----	J. B. Rishel...	Williamsport, Pa.	Apr. 30, 1923	Apr. 30, 1923	Williamsport, Pa.
†103323	-----	H. E. Childs..	Rockville, R. I..	June 30, 1922	July 1, 1922	Rockville, R. I.
†104324	-----	H. M. Halverson.	Yankton, S. Dak.	June 23, 1923	June 24, 1923	Yankton, S. Dak.
†69478	-----	Mrs. H. C. Miller.	Racine, Wis.....	Apr. 16, 1923	Aug. 1, 1923 ²	Racine, Wis.
104203	-----	Mrs. E. M. Towns.	Milwaukee, Wis	June 26, 1922	May 11, 1923	Milwaukee, Wis.
†112451	-----	do.....	do.....	May 14, 1923	May 24, 1923	Do.

² Date approximate.

Bluebird: *Sialia sialis*

No.	Age and sex	Banding record			Return record	
		Operator	Locality	Date	Date	Locality
*†55415	-----	W. I. Lyon...	Waukegan, Ill...	May 23, 1922	June 19, 1922	Waukegan, Ill.
†11492	-----	Mrs. B. P. Reed	Lawrence, Kans	May 12, 1922	May 15, 1922	Lawrence, Kans.
†12503	-----	do.....	do.....	June 27, 1922	June 27, 1922	Do.
17236	♀	G. E. Allen...	Plainfield, Mass.	May 31, 1922	Apr. 2, 1923	Plainfield, Mass.
17214	♀	Mrs. E. L. Hathaway.	West Bridgewater, Mass.	Aug. 8, 1922	May 9, 1923	West Bridgewater, Mass.
†29904	-----	A. W. Higgins.	Rock, Mass.....	May 24, 1922	May 28, 1922	Rock, Mass.
24572	♂	E. U. Ufford..	Auburndale, Mass.	-----do-----	June 7, 1923	Auburndale, Mass
†28605	-----	Fr. Damian Smith	Manchester, N. H.	July 18, 1922	Sept. 8, 1922	Manchester, N. H.
*45941	♀	S. P. Baldwin.	Gates Mills, Ohio.	June 6, 1920	July 7, 1921	Gates Mills, Ohio.
*45947	♂	-----do-----	-----do-----	June 7, 1920	June 2, 1921	Do.
14912	-----	-----do-----	-----do-----	June 25, 1922	June 24, 1923	Do.
11957	♀	H. E. Childs..	Providence, R. I	May 19, 1922	Aug. 8, 1922 ¹⁰	Providence, R. I.
11958	♂	-----do-----	-----do-----	May 21, 1922	Aug. 8, 1922 ¹⁰	Do.

¹⁰ Retrapped at nest box for second brood.

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October 14, 1924

THE BUD MOTH

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INTRODUCTION

For many years the unfolding leaves and blossom buds in the apple orchards of the northern part of the United States and of southern Canada have been seriously injured by the small brown larvæ of the bud moth, *Spilonota ocellana* (D. & S.). This bulletin presents the results of studies of this species carried on in 1920 and 1921 at the field station maintained at Wallingford, Conn., for the study of fruit insects, by the Bureau of Entomology, in cooperation with the Connecticut Agricultural Experiment Station at New Haven.¹

HISTORICAL

The native home of the bud moth seems to be Europe, where it has been mentioned in entomological literature since 1776, when it was described by Denis and Schiffermüller (1)² under the name *Tortrix ocellana*. The bud moth was presumably introduced into the United States with the early importations of apple and other nursery stock, but no mention seems to have been made of it until 1841, when Harris (3) gave a short account of it under the name *Penthina oculana*. During the next 40 years only occasional short mention of the pest was made.

¹ The work of the Wallingford station has been under the direction of Dr. A. L. Quaintance. The writer was assisted in 1920 by C. H. Alden and in 1921 by H. M. Tietz. The writer wishes also to thank Carl Heinrich, of the Bureau of Entomology, for assistance in the preparation of the description of the full-grown larva, and R. A. Cushman, A. B. Gahan, and Dr. J. M. Aldrich for parasitic determinations.

² Numbers in parentheses refer to "Literature cited," p. 19.

In 1856 Fitch (7, p. 345-346) mentioned it under the name *Spilonota oculana* and stated that it was probably identical with *ocellana* D. & S., *luscana* Fab., and *comitana* Hübner, Stephens, and others. In 1860 Clemens (8) described the species under the name *Hedya pyrifoliana*. In 1869 (9), in reply to a Pennsylvania correspondent of the American Entomologist, it was stated that larvæ which had been sent in for determination were probably *Spilonota oculana* (Harris), and that the species did not occur in the West. In 1871 the bud moth was reported in Ontario, and in mention of the species in 1885 Fletcher (12) expressed the opinion that hibernation occurred in the larval stage in tiny silken nests on the branches of the apple trees. This observation was verified by others during the course of the next few years. In 1888 Fernald (13) recommended the use of Paris green for the control of the pest, and in a bulletin published in 1891 (15) gave considerable historical information and added to our knowledge of the biology of the species. About this time the bud moth was reported from numerous additional localities in the New England States, New York, Ohio, and Michigan.

In 1893 Slingerland (16) published an extensive and accurate account of the bud moth, and, since the publication of his work, increasingly frequent mention has been made of the species in experiment station bulletins and other entomological literature.

About 1895 (17) the bud moth was reported from Genesee, Idaho, from St. Elmo, British Columbia, and within the next few years from numerous localities in the adjoining States of Montana, Washington, and Oregon, and from new localities in British Columbia.

In connection with experimental work carried on by the Bureau of Entomology in Michigan in 1913, Scott and Paine (18) undertook a study of a species of larva working in apple buds, assumed at that time to be the only bud moth. Before the investigation had progressed very far, however, the discovery was made that the insect under observation was not *Spilonota ocellana*, but an entirely distinct species, which was later identified as *Recurvaria nanella* (Hbn.) to which was given the name "the lesser bud moth." This species has been reported from numerous localities from Maryland to Nova Scotia, and westward to Michigan. The life history of the lesser bud moth parallels rather closely that of the true bud moth during the winter and early spring. In early spring the work in the foliage is most noticeable, and without doubt more or less of the injury attributed to *Spilonota ocellana* in the eastern portion of its range has in reality been the work of the lesser bud moth.

In 1919 Sanders and Dustan (22) published an account of the bud moths in Nova Scotia, and added two more species, *Cacoecia rosaceana* (Harris) and *Olethreutes consanguinana* Wlsm., to the two already known to winter as larvæ in silken hibernacula and to feed in the unfolding buds in the spring.

SYNONYMY

The following list of synonyms does not include all of the numerous genera to which the species has been referred from time to time. In recent years the species for the most part has been incor-

rectly placed in the genus *Tmetocera* Lederer. The species *comitana* Hbn., a synonym of *ocellana* D. and S., was designated by Curtis (2) in 1835 as the type of the genus *Spilonota* Stephens. *Tmetocera* is, therefore, identical with the older genus *Spilonota* Stephens.

The variety *lariciana* Heinemann, said to have been reared in Europe from the larch, has been reared in the United States from apple foliage, but there is no American record of it as a larch feeder.

Spilonota ocellana (D. & S.)

Tortrix ocellana Denis and Schiffermüller, 1776, in Syst. Verzeichn, Schmett. Wien, p. 130.

Pyralis luscana Fabricius, 1794, in Ent. Syst., t. 3, p. 2, p. 255.

Tortrix comitana Hübner, 1800, in Samml. Eur. Schmett., v. 5, Lepidop, VII, Tortrices II, pl. 3, fig. 16.

Spilonota comitana (Hübner) in Stephens, 1829, Cat. Brit. Insects, pt. 2, p. 174, No. 6914.

Penthina oculana Harris, 1841, in Treatise on Insects, p. 348-349.

Tmetocera ocellana (D. & S.) in Lederer, 1859, Wien. Ent. Monatschr., Nr. 12, Band 3, p. 367-368.

Hedya pyrifoliana Clemens, 1860, in Proc. Phil. Acad. Sci., p. 357.

var. *lariciana* Heinemann 1863, in Schmett. Eur. Deutsch., Bd. 1, Heft. 1, Abth. 2.

COMMON NAME

This insect has been variously called the bud moth, the bud worm, and the eye-spotted bud moth. The last name has been very generally used, and refers to certain more or less eyelike markings on the forewings of the moth. The moths themselves, however, are seldom noted by any but entomologists, and the first part of this name has little significance to the average fruit grower, although he is usually all too familiar with the work of the larvæ in the fruit buds. The name officially adopted for this species by the American Association of Economic Entomologists is the bud moth, and this name will be used in this bulletin.

FOOD PLANTS

The following list of food plants, which has been brought together from all available sources, shows the bud moth to be a very general feeder.

<i>Alnus</i> sp. ³ -----	Alder.
<i>Carpinus</i> sp.-----	Hornbeam.
<i>Crataegus</i> sp.-----	Hawthorn.
<i>Chaenomeles lagenaria</i> (Loisel.)-----	Japanese quince.
<i>Cydonia oblonga</i> Mill-----	Quince.
<i>Fagus sylvatica purpurea</i> Ait-----	Purple beech.
<i>Larix</i> sp. ³ -----	Larch.
<i>Myrica gale</i> L. ³ -----	Sweetgale.
<i>Amygdalus persica</i> L-----	Peach.
<i>Prunus</i> spp-----	Cherry, plum, prune, etc.
<i>Pyrus communis</i> L-----	Pear.
<i>Malus sylvestris</i> Mill-----	Apple.
<i>Pyrus</i> spp-----	Flowering crab, crab apple, etc.
<i>Quercus imbricaria</i> Michx-----	Shingle oak.
<i>Quercus</i> sp-----	Oak.
<i>Rubus</i> spp-----	Blackberry, raspberry.
<i>Sorbus aucuparia</i> L. ³ -----	European mountain-ash.

³ Recorded as a food plant in Europe but not in North America.

DISTRIBUTION

The exact distribution of the bud moth has been difficult to ascertain, as the unfortunate confusion of the bud moth with numerous species similar to it has doubtless given rise to a number of erroneous records. The map (fig. 1) shows the distribution of this species in North America as indicated by available records.

The extension of the range of the bud moth south of the District of Columbia is based on reports in the correspondence files of the Bureau of Entomology of its presence at Amherst Court House and Waldrop, Va., Oakwoods, N. C., and McIntyre, Ga. Through this section the pest is apparently present at most in very small numbers. A similar condition seems to exist in the Middle West. R. L. Webster writes from North Dakota that he has no definite record of the bud moth from that State. Fracker writes that, while the bud moth has

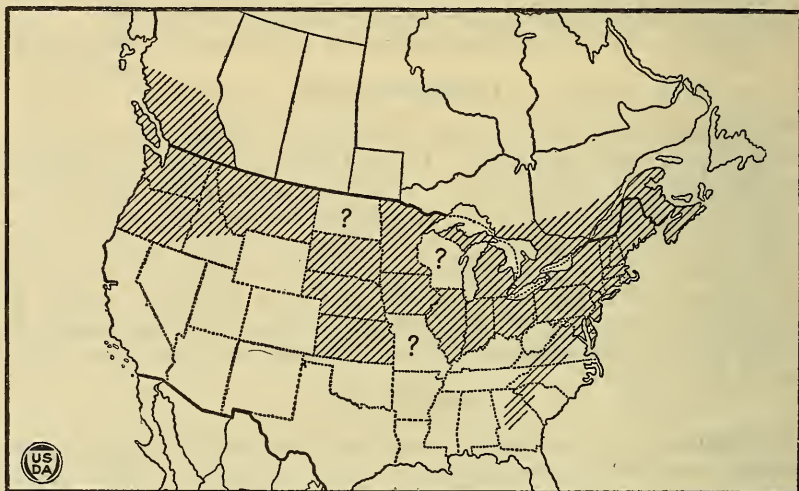
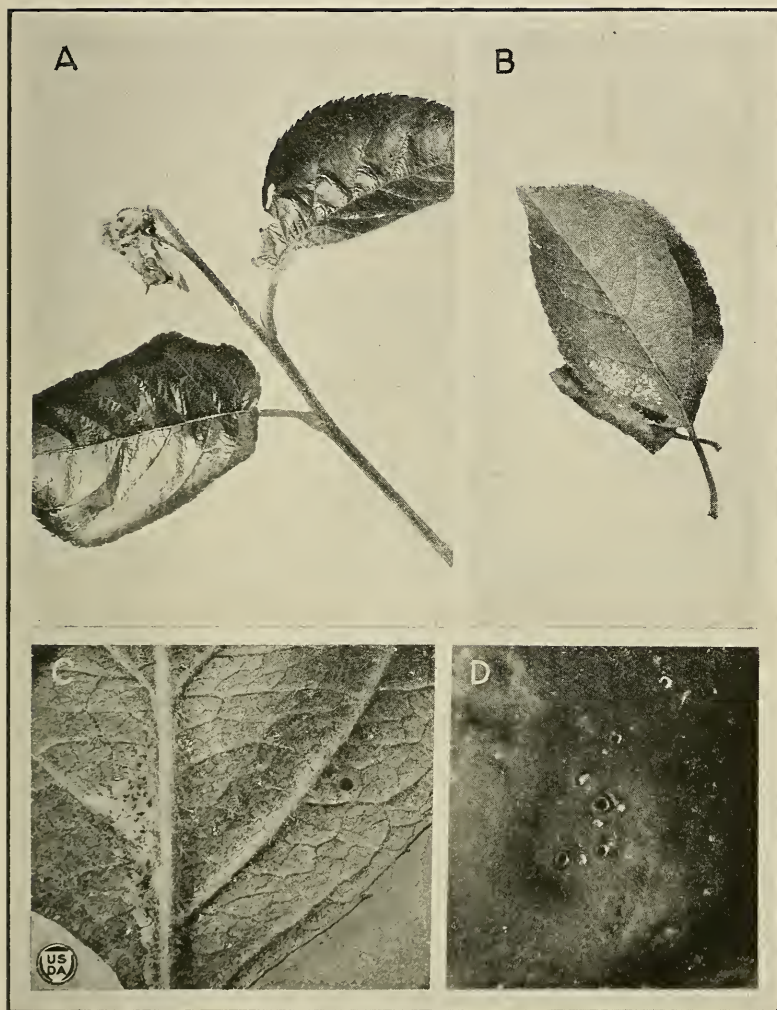


FIG. 1.—Distribution of the bud moth in North America.

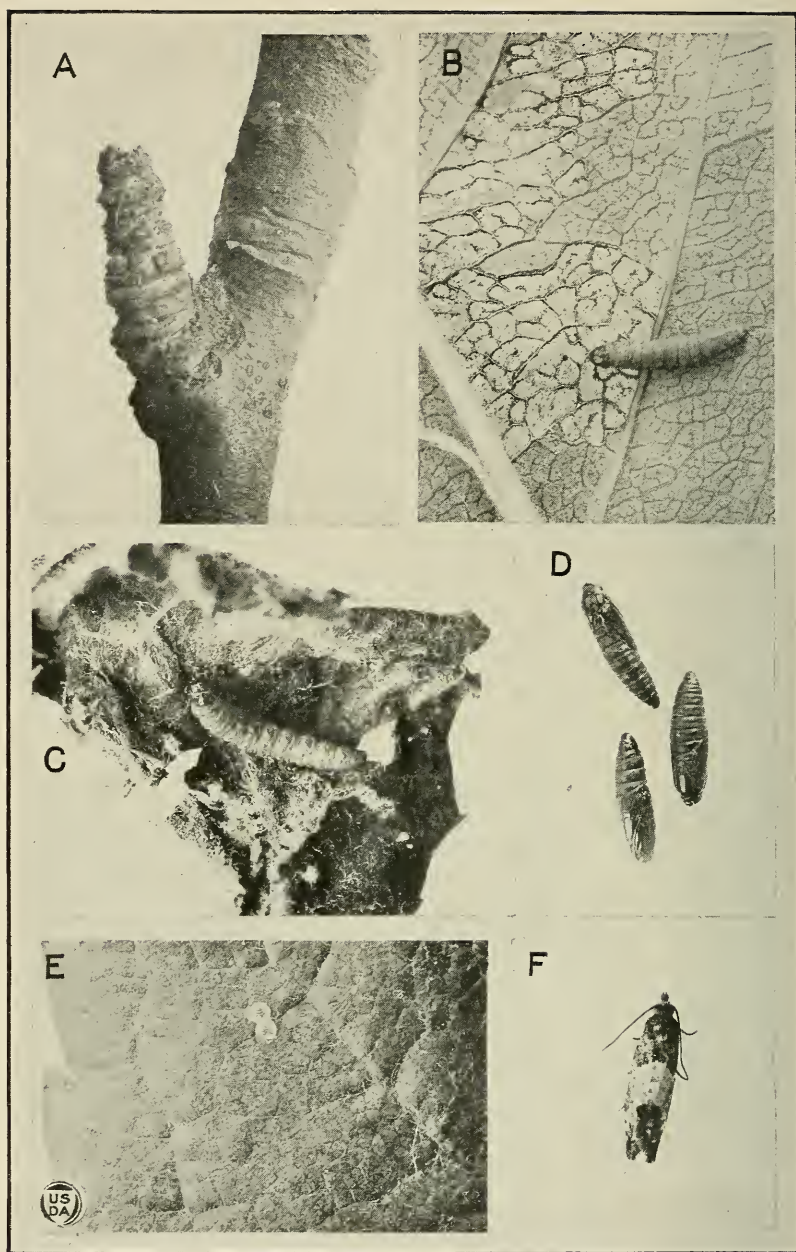
been mentioned as occurring in Wisconsin, specimens accompanying such reports have always turned out to be the leaf crumpler, *Mineola indigenella* Zeller. Haseman, writing from Missouri, states that there seem to be no official records of the presence of *Spilonota ocellana* in that State. Dwight Isely, formerly of this bureau, reports that in the course of extensive collecting he has never seen the bud moth in Arkansas, or anywhere in the Ozarks. The pest is mentioned in experiment station publications from the other midwestern States, but apparently is not present in serious abundance. The areas of most serious infestation seem to be southeastern Canada, the Northeastern States, northwestern group of States, and British Columbia.

The bud moth is said to occur throughout the British Isles and Europe, except in the most southern countries.



WORK OF THE BUD MOTH

A, One type of spring foliage injury ($\times \frac{1}{2}$); B, late summer foliage injury ($\times \frac{1}{3}$); C, summer feeding shelter ($\times 2\frac{1}{2}$); D, late summer injury to the fruit ($\times 2$)



BUD MOTH

A, Hibernaculum ($\times 3\frac{1}{2}$); B, nearly full-grown larva on leaf ($\times 2\frac{1}{2}$); C, full-grown larva in torn-open nest in dead leaf ($\times 2\frac{1}{2}$); D, pupae ($\times 3$); E, eggs on leaf ($\times 4$); F, moth ($\times 2\frac{1}{2}$)

MEANS OF DISSEMINATION

While fairly extensive local distribution of this insect may be effected by the flight of the moths, by far the most important factor in its widespread dissemination has been the ease with which it may be carried on nursery stock, owing to the difficulty of detecting it during the dormant season. The hibernacula are usually tucked away in some inconspicuous crevice or corner. Even when not so concealed they are difficult to find, so closely do they resemble the surrounding bark. There is no doubt that this pest owes its present extensive distribution largely to the fact that it has been repeatedly transported to new localities on stock from infested nurseries, both from this country and from Europe.

ECONOMIC IMPORTANCE

Although usually placed among the lesser insect pests of the apple, the bud moth often does serious damage, and its importance is usually underestimated. The commercial loss caused by this species has been estimated to be as high as 30 per cent in severe infestations, although a loss as great as this is doubtless unusual. In the spring the half-grown larvæ feed to some extent in the unopened blossoms, reducing very materially the amount of fruit which sets and causing in years of light crops an especially serious loss, the extent of which is seldom fully realized. When larvæ are numerous the leaves may be considerably injured, much foliage being used for the larval nests in addition to the amount actually consumed. Larvæ sometimes ruin the growing shoots by killing the terminal leaf for use as a nest, or by burrowing inside the shoot. After the fruit sets it is occasionally eaten into by the nearly full grown larvæ, and drops off or becomes deformed and disfigured. In late summer the foliage injury by the tiny worm (Pl. I, B) is not as extensive or as serious as in the spring, but the larvæ often feed to some extent on the fruit, making numerous small, shallow blemishes (Pl. I, D).

OTHER SPECIES OF BUD MOTH

A few of the numerous leaf-feeding species of insects infesting apple foliage in early spring have certain life-history details in common with the bud moth, and are likely to be confused with it. Short accounts of a few of these species follow.

LESSER BUD MOTH

The lesser bud moth, *Recurvaria nanella* (Hbn.) (18), until 1914 was confused with the bud moth, and very possibly its work is often still identified as being that of *Spilonota ocellana*. The lesser bud moth winters over in hibernacula very similar to those constructed by the bud moth, although not always placed as close to the buds. Larvæ of this species emerge a few days earlier in the spring than those of the bud moth—sometimes before the buds have expanded to any extent. Their feeding shelters in the leaves are usually constructed in living rather than dead foliage. On emergence from

hibernation, larvæ of this species are often mistaken for those of *Spilonota ocellana*, but are a more reddish brown, which later turns to greenish brown or green. In the late summer the young larvæ are leaf-miners, and are not likely at this time to be confused with the bud moth.

OBLIQUE-BANDED LEAF-ROLLER

In Nova Scotia (22) the oblique-banded leaf-roller, *Cacoecia rosaceana* Harris, winters over as a partly grown larva in a hibernaculum similar to that made by other species of bud moth, but smaller, and more often constructed under a dead bud scale. At Wallingford, Conn., a single moth of this species was reared from a larva which emerged early in the spring of 1922 from a similar hibernaculum. Emergence from hibernation takes place in the spring at the same time as that of the lesser bud moth. The larva at this time is dirty yellow to brownish. After the leaves expand, this species feeds as a leaf-roller, and is not likely to be confused with the bud moth.

OLETHREUTES CHIONOSEMA Zeller

Adults of this species were reared at Wallingford, Conn., in 1921 from larvæ found in the buds just as they were unfolding in the spring, and in 1922 from larvæ emerging from winter shelters very similar to bud moth hibernacula.

GREEN BUDWORM

The green budworm, *Olethreutes consanguinana* Wlsm., has been reported as an apple feeder in Nova Scotia (22) only. It winters as a partially grown larva in a hibernaculum, much as do the other species already mentioned. After emergence in the spring, a confusion with other species of bud moth is not very probable. The larvæ of this species are green with a black head, and in the spring they feed as leaf-rollers, not confining themselves as closely to the nests as does the true bud moth.

THE LEAF CRUMPLER

The leaf crumpler, *Mineola indigenella* Zeller, hibernates as a partly grown larva. Its winter shelter, which is larger and much more conspicuous than that of the bud moth, is tubular and often hidden in a small mass of crumpled leaves. The larva is considerably larger than that of the bud moth, but its color is somewhat similar.

DESCRIPTION OF STAGES OF THE BUD MOTH

EGG

Pl. II, E

. Flattened, rounded oval in shape, varying somewhat in outline. Length 0.72 to 0.99 millimeter, average 0.83; width 0.55 to 0.77 millimeter, average 0.67. Pale watery white in color, almost transparent when first laid, with an iridescence in some lights. Faintly sculptured with reticulate lines, which are more clearly visible along the edges. As the development of the embryo progresses, the egg material shrinks from the edges, leaving a thin, narrow flange-like margin.

LARVA

In Wallingford some individuals passed through six larval instars and others through seven, but except for a slight difference in size there seem to be no noticeable differences between the two.

Full-grown larva (Pl. II, B, C).—Width of head 0.94 to 1.16 millimeters; average 1.05. Length 11 to 13 millimeters. General color dull brown; head from medium brown to nearly black, shiny; thoracic shield shiny, dark brown to black, divided in the middle by a longitudinal paler line; mouth parts brown, lighter than head; antennæ pale at base, darker at tips; anal shield dark; ventral surface paler than dorsal; thoracic legs dark brown, almost black, shiny; prolegs pale, crotchets biordinal and in a complete circle, 32 to 48 in number; surface of body finely granulate; tubercles darker than surrounding body surface, finely lined, shiny, with darker dots at bases of setæ; chitinization about thoracic tubercles very large; three setæ on prespiracular shield of thorax in longitudinal line; setæ IV and V on proleg-bearing abdominal segments under spiracles closely approximate and on the same chitinization; paired setæ II on ninth abdominal segment on one chitinization and closer together than paired I on dorsum of eighth abdominal segment; II and III on ninth abdominal segment on the same chitinization and closely approximate; eighth abdominal seta III directly anterior to spiracle; a short, small anal fork with 2 to 5 prongs of irregular length.

First stage.—Width of head 0.22 millimeter; length when newly hatched 1.05 to 1.27 millimeters; length when full fed about 2 millimeters. When newly hatched, the larva is white; head shiny black; thoracic shield very dark gray, almost black; anal plate gray, paler than thoracic shield; ventral surface much the same color as dorsal; thoracic legs dusky; prolegs concolorous with the body. Body with sparse, long, white hairs. After feeding a few days the larva becomes a dirty yellowish white, and then light brown.

Second stage.—Width of head 0.28 to 0.39 millimeter, average 0.33; length when full fed 2.5 to 3 millimeters. General color light brown; head very dark brown to black, shiny; thoracic shield the same; anal shield darker brown than the body, but not nearly as dark as thoracic shield; venter much the same color as dorsal surface; thoracic legs very dark brown to black, shiny; prolegs concolorous with the body; tubercles distinct; hairs creamy white, moderately long, sparse.

Third stage.—Width of head 0.39 to 0.52 millimeter; average 0.45. Length when full fed 3.5 to 4 millimeters. General color dull brown; head a shiny black; thoracic shield shiny, very dark brown, practically as dark as head; anal shield dark brown, shiny; ventral surface not quite so dark a brown as dorsal; true legs dark brown; prolegs somewhat paler than adjacent body surface; tubercles distinct, shiny; hairs moderately long, sparse, white.

Fourth stage. (Hibernation usually occurs in this instar, the larva molting during the construction of the hibernulum.)—Width of head 0.41 to 0.55 millimeter, average 0.50; length in hibernating condition about 3 millimeters; length when full fed after emergence in the spring about 5 millimeters. Body color an almost uniform cinnamon brown, with some variation from darker to lighter; head and thoracic shield a dark shiny brown, head a little darker, almost black; thoracic shield a little lighter on anterior margin; anal plate from concolorous with the body to a little darker; thoracic legs a somewhat darker brown than the body; prolegs concolorous with the body; mouth parts brown, paler than head; tubercles conspicuous, concolorous with the body, shiny; hairs sparse, short, white.

Fifth stage.—Width of head 0.66 to 0.80 millimeter, average 0.71; length when full fed 7.5 to 8.5 millimeters. General color a dull brown, sometimes with an olivaceous tinge; head and thoracic shield dark brown to black, shiny; mouth parts brown; antennæ pale basally, darker toward tips; anal plate dark greenish brown; ventral surface not quite so dark as dorsal; thoracic legs piceous, shiny; prolegs about concolorous with the ventral surface, with a dark area on outer side; tubercles with a minute dark dot; hairs sparse, white.

PUPA

Pl. II, D

Female.—Length 6 to 7 millimeters; width at widest point 1.8 to 2 millimeters. Color golden brown, deeper at head, wing pads, anal segment, and

spiracles. Dorsal abdominal segments 2 to 7 each with two transverse rows of short bristles pointing backwards, one row near each margin of the segment, that on the anterior margin frequently overlapped and concealed by the segment anterior to it. Spines in the posterior row of each segment much smaller than those in the anterior row. Dorsal segments 8 to 10 each with a single row of spines; those on segment 9 somewhat stouter, and those on segment 10 very much stouter than those on other segments. Cremaster absent; anal segment with 8 bristles, curved outward at their tips, arranged somewhat in a circle, four singly and two pairs. Abdomen minutely pitted. Spiracles somewhat raised and rounded.

Male.—Same as female, but a little smaller.

MOTH

Pl. II, F

Fernald (15) describes the moth as follows:

The fore wings expand about three-fifths of an inch. The head, thorax and basal third of the fore wings, and also the outer edge and fringe are dark ash gray, the middle of the fore wings is cream white, marked more or less with costal streaks of gray, and in some specimens this part is ashy gray, but little lighter than the base. Just before the anal angle are two short horizontal black dashes followed by a vertical streak of lead blue, and there are three or four similar black dashes before the apex, also followed by a streak of lead blue.

The hind wings above and below and the abdomen are ashy gray. The under side of the fore wings is darker, and has a series of light costal streaks on the outer part.

SEASONAL HISTORY AND HABITS

The bud moth has one generation every 12 months, commencing with the egg stage in midsummer and ending with the deposition of eggs for the succeeding generation during midsummer of the following calendar year.

It passes the winter as a partially grown larva in a tiny silken nest, or hibernaculum (Pl. II, A), placed in any convenient crevice, or other place. Du Porte (19) found that in Quebec hibernation occurred in the third, fourth, and fifth stages. Under Connecticut conditions practically all larvæ enter hibernation at the end of the third stage and molt during the construction of the hibernaculum, although occasionally a few individuals pass the winter in the following stage.

Emergence from hibernation occurs early in the spring, sometimes as the buds are just beginning to show green, but more often a little later, as the buds are unfolding. In Connecticut the lesser bud moth, *Recurvaria nanella*, which at this point in its life history follows closely that of the bud moth, has a tendency to emerge earlier, and frequently enters the buds before they have expanded to any extent. While the bud moth occasionally emerges equally early, it is more likely to wait until the leaves are just beginning to unfold before leaving winter quarters. Once in a while a larva after emergence and a short period of feeding in an unfolding bud will return to its hibernaculum, usually because of unfavorable weather, leaving behind a trail of silk.

In 1920 and 1921, the emergence of the larvæ from hibernation was carefully observed. Infested material was brought in and short lengths of twigs which bore hibernacula were placed in cages. These were kept in the insectary under out-of-door conditions except

for a few moments each day, when the material was brought inside for examination and removal of the larvæ which had emerged. The emergence as observed by this method seemed to agree for the most part very closely with conditions noted in the field, except the latter part of the 1921 emergence, which continued intermittently for about two weeks after it was apparently complete in the field. In a few instances the presence of an opening in a hibernaculum loosely covered with fresh silk gave evidence that a larva had left its winter nest, but not finding fresh foliage in the cage, had returned to its winter quarters to await more favorable conditions. With this exception, Table 1 undoubtedly indicates very closely what was occurring in the field. In 1920 the season was approximately two weeks later than the normal season, but from May 6, when the bud moth larvæ commenced leaving their winter quarters, the weather continued fairly warm, and evidently favored rapid emergence. In 1921 the season was on the whole two weeks ahead of normal, but the extreme warm periods alternated with cooler weather, which explains in part the straggling emergence which occurred.

TABLE 1.—*Emergence of the bud moth from hibernation, Wallingford, Conn.*¹

IN 1920

Date	Number emerged	Temperature			Date	Number emerged	Temperature		
		Maxi- mum	Mini- mum	Aver- age			Maxi- mum	Mini- mum	Aver- age
		° F.	° F.	° F.			° F.	° F.	° F.
May 3.....	-----	53	39	44.7	May 9.....	17	72	47	59.3
4.....	-----	50	35	42.6	10.....	5	75	49	59.1
5.....	-----	62	31	46.3	11.....	7	66	49	54.7
6.....	1	68	36	51.5	12.....	4	66	44	56.0
7.....	11	68	41	53.8	13.....	4	57	47	50.5
8.....	11	53	48	51.0	14.....	2	54	45	48.7

IN 1921

Date		° F.	° F.	° F.	Date		° F.	° F.	° F.
Apr. 4.....	-----	70	42	55.3	Apr. 22.....	3	78	49	60.9
5.....	-----	81	49	64.1	23.....	5	64	45	52.2
6.....	2	78	50	62.0	24.....	6	67	42	54.3
7.....	-----	46	39	41.5	25.....	3	76	47	59.2
8.....	5	58	39	47.3	26.....	-----	73	44	57.6
9.....	7	71	46	57.7	27.....	-----	68	51	58.4
10.....	-----	53	33	44.0	28.....	1	73	56	64.0
11.....	4	47	29	36.3	29.....	-----	72	51	59.8
12.....	13	61	33	46.4	30.....	-----	58	49	53.8
13.....	6	68	37	51.8	May 1.....	2	52	44	47.5
14.....	10	70	44	55.7	2.....	1	68	42	52.4
15.....	7	57	51	54.2	3.....	-----	70	47	55.8
16.....	5	63	52	56.7	4.....	-----	64	48	54.8
17.....	1	57	46	53.9	5.....	-----	47	44	45.1
18.....	-----	44	34	37.4	6.....	2	49	45	47.0
19.....	3	47	34	40.9	7.....	2	62	41	51.0
20.....	4	73	36	54.0	8.....	2	73	45	56.9
21.....	2	76	49	60.5					

¹ Temperatures in Table 1 are from thermograph records; 24 hourly temperatures used in calculating averages.

On emerging from winter quarters the larva makes its way to a bud or an unfolding cluster of leaves. If the bud has not yet

opened, the larva chews its way into it from the outside, but if the leaves are unfolding, as is usually the case, it makes its way into the heart of the cluster, leaving little external evidence of its presence. When not feeding, it conceals itself in any convenient place—the curled edge of an unexpanded leaf, or among the stems at the base of the cluster. After feeding for a short time, sometimes in the unopened blossom buds, and sometimes on the foliage, the larva constructs a tubular nest, usually in a fold or the curled portion of a leaf, sometimes between two leaves which touch. All large gaps are closed, and the nest is lined with silk, in which are frequently embedded bits of leaf tissue and more or less frass. The leaf in which the nest is constructed is often partially severed at the base, causing it to wilt and turn brown, and is usually attached with silk to an uninjured leaf or stem, which prevents the nest from falling when the leaf dies. Sometimes the nest is made in the terminal leaf of a shoot (Pl. I, A). While the leaf in which the nest is constructed is still green, the larva feeds on it, but as the leaf dies and becomes dry the larva goes out to feed on adjacent leaves, at first skeletonizing small areas on either surface of the leaf, and later sometimes consuming entire sections of leaf. In some cases the larva burrows into and down one of the growing shoots, causing the tip to die. While the larval nests are occasionally constructed in other places, the great majority of them are to be found in dead leaves. The lesser bud moth and the leaf-rollers are more likely to make their headquarters in living leaves, which are rolled, curled, folded, or tied, as the case may be. The lesser bud moth often webs together the tip of the leaf cluster, which bulges out as the leaves grow. Occasionally the bud moth will desert its nest and construct another.

Efforts to observe closely the successive molts as they occurred have been only partially successful, as the unavoidable necessity of disturbing the larvæ in their nests for the purpose of making observations brings about a high mortality. By starting with a large number of individuals, however, it was determined in the spring of 1921 that some of the larvæ molt twice in the spring and others three times, except in the occasional instances where hibernation is delayed until the fifth stage, in which case the number of molts in the spring is one less than usual. This makes the number of stages six in some cases, and seven in others. Sixth-stage larvæ which are to pass through a seventh stage are somewhat smaller than those completing their development in the sixth stage, but the measurements overlap, and it is impossible to determine to which stage a nearly full-grown larva belongs, unless observations have been made at regular intervals since emergence from hibernation.

Besides feeding on the leaves and growing shoots, the larvæ when nearly full-grown occasionally attack the newly set fruit, causing it to drop off, or become deformed and disfigured by an extensive corky area.

When the feeding period is at an end, the larva makes preparations for pupation. In some cases it remains in its feeding shelter; in others it deserts this place, and finds another sheltered spot, in a

curled leaf, or elsewhere, and lines the place chosen with silk. At this time the larva loses much of its brown color, becomes a dirty grayish white, and also becomes somewhat shortened. In this condition it may continue several days or even a week before pupation finally takes place.

In both 1920 and 1921, a number of larvæ were collected in the field when nearly full grown, and the exact dates of pupation and emergence were noted, the resulting data being presented in Table 2.

TABLE 2.—*Pupation and emergence of the bud moth, Wallingford, Conn.*

IN 1920

Pupated	Emerged	Number of individuals	Days	Pupated	Emerged	Number of individuals	Days
June 3.....	June 24	1	21	June 22.....	July 8	3	16
11.....	29	1	18	23.....	8	3	15
12.....	29	3	17	24.....	8	1	14
13.....	29	2	16	24.....	9	2	15
13.....	July 1	2	18	24.....	10	4	16
14.....	1	3	17	25.....	9	1	14
15.....	1	2	16	25.....	10	3	15
15.....	2	2	17	25.....	11	1	16
15.....	3	1	18	26.....	11	1	15
16.....	3	1	17	26.....	12	1	16
16.....	4	1	18	27.....	12	3	15
16.....	5	2	19	28.....	12	2	14
17.....	4	1	17	28.....	14	1	16
17.....	5	2	18	29.....	14	1	15
20.....	7	2	17	30.....	14	4	14
21.....	8	1	17	July 2.....	16	1	14
22.....	7	2	15	11.....	24	1	13

IN 1921

May 28.....	June 15	1	18	June 13.....	June 28	2	15
31.....	18	1	18	13.....	30	1	17
31.....	20	1	20	14.....	29	1	15
June 3.....	20	1	17	15.....	29	1	14
3.....	21	2	18	15.....	30	1	15
5.....	23	1	18	15.....	July 1	1	16
6.....	22	1	16	16.....	1	2	15
6.....	24	1	18	16.....	2	1	16
7.....	22	1	15	19.....	3	2	14
7.....	24	1	17	19.....	4	1	15
7.....	25	2	18	20.....	3	1	13
8.....	23	1	15	20.....	4	1	14
9.....	24	1	15	21.....	4	2	13
10.....	24	1	14	22.....	6	1	14
10.....	25	1	15	23.....	7	1	14
11.....	25	2	14	23.....	8	1	15
11.....	26	1	15	24.....	8	2	14
11.....	27	3	16	26.....	9	2	13
12.....	26	1	14	July 3.....	15	1	12
12.....	27	2	15	3.....	16	1	13
12.....	28	1	16				

Table 3 gives data regarding the duration of the period of pupation under Connecticut conditions in 1920 and 1921, summarizing Table 2. The period varies from 12 to 21 days, with an average of 15 to 16 days.

TABLE 3.—*Period of pupation of the bud moth, Wallingford, Conn., 1920 and 1921—Summary of Table 2*

Number of days	Number of individuals	
	1920	1921
12 days.....	0	1
13 days.....	1	6
14 days.....	9	12
15 days.....	15	15
16 days.....	14	7
17 days.....	13	3
18 days.....	7	8
19 days.....	2	0
20 days.....	0	1
21 days.....	1	0
Total.....	62	53
Average number of days..	16	15.3

The emergence of the moths covers a period of a month or more, following from two to three weeks after pupation. In 1920, the moths were emerging in the insectary from June 24 to July 24; in 1921, a single moth was noted in the field on June 8, and moths emerged in the insectary from June 15 to July 16.

The moths are active chiefly at night, and are not often noted in the daytime. Mating was not observed in the insectary at Wallingford, but apparently occurred at night, and fertile eggs were laid in fair numbers in the jars used for oviposition. Egg-laying commenced in from 2 to 5 days after emergence, usually on the second or third day, and continued from 1 to 11 days, although the greater part of the eggs were usually laid during the first 2 or 3 days of oviposition. Confined in battery jars, some of the moths refused to lay at all; others deposited a few eggs, while others laid very freely. The greatest number of eggs laid by any one moth was 156. Eggs were deposited on both sides of apple or pear foliage, usually singly, but occasionally several overlapping one another. In captivity one female moth lived 15 days and a male 16 days, the average length of life in 1920 being 7.5 days for the females and 7 days for the males. In 1921 the average was 11.6 days for the females and 12.2 days for the males.

Four or five days after the eggs are laid, the exact length of time depending upon weather conditions, certain changes become evident. At this time two dark dots become visible through the thin shell of the egg, indicating the presence of the two groups of ocelli. In six or seven days the brown mandibles and other mouth parts appear; shortly afterwards the dark head and thoracic shield become evident, and the outline of the larva becomes very faintly visible. At the end of the seventh day occasional larvæ hatch if the weather has been especially warm, but the greater part of them hatch in 8 to 10 days, the incubation period, according to Table 4, being approximately 9 days under ordinary midsummer conditions in Connecticut.

TABLE 4.—*Incubation of eggs of the bud moth, Wallingford, Conn., 1920*

Eggs laid	Eggs hatched	Number of eggs	Days
July 8---	July 15	29	7
	16	15	8
9---	17	18	8
10---	19	19	9
	20	27	10
11---	20	8	9
12---	21	73	9
	22	9	10
13---	22	93	9
14---	23	124	9
15---	24	21	9
	25	29	10
Total eggs.....		465	-----
Average incubation period...			9

After hatching, the larva wanders about on the leaves for a short period. During this time it may gnaw small pits in the leaf tissue and spin a small amount of silk, but it soon settles in one spot and constructs a shelter. This may be located anywhere on either surface of the leaf, but the preference seems to be for the lower surface next to one of the larger veins or the midrib, although often the place chosen is where two leaves or a leaf and an apple touch. The larva then constructs a weblike shelter over itself and the greater part of its feeding grounds, often embedding in the silk more or less frass, bits of leaf tissue, and leaf hairs. Later in the stage the shelter takes the form of a tube open at both ends under a rooflike silken web (Pl. I, C). When newly hatched the larva is white, but after a few days of feeding it becomes first a dirty yellowish white, and then a light brown. As the larva grows, the amount of frass included in the tubular portion of the nest increases until it becomes dark brown or black, while the flat web above is light, loosely woven, and includes only a few loose bits of frass. If constructed next to a straight midrib or vein, the tube is straight; in other cases it may be more or less curved and irregular in shape. In feeding, the larva eats through to the opposite epidermis, which becomes dry and brown. As feeding continues and the larva increases in size, the shelter is extended to cover most of the feeding ground, and the tubular nest is lengthened. If the nest has been constructed between a leaf and an apple, the larva frequently gnaws tiny pits through the skin of the fruit. If feeding takes place between two leaves the leaves are webbed together, and if next to an apple the leaf is fastened to it. As feeding continues the area consumed is increased, but the larva very rarely eats through the opposite epidermis of the leaf. All larvæ observed passed through at least three stages, and in rare cases four, before entering hibernation.

Several weeks before the coming of cold weather, as the larvæ approach the end of the third or rarely the fourth stage, they begin to desert the leaves to seek quarters for the winter. The earliest date on which larvæ were found in hibernation in Connecticut in the summer of 1920 was August 21; in 1921 it was August 25, and it was six weeks or more before all larvæ had left the leaves. In 1921 infested twigs were brought in at intervals and record made of the number of larvæ in hibernation and those still feeding. These ob-

servations, expressed in percentages, are presented in Table 5. Extremely cool weather apparently has little to do with the entering of the larvæ upon the hibernation period, as up to September 30, the date on which nearly all larvæ had left the foliage, the lowest minimum temperature had been 44° F., on September 27.

TABLE 5.—*Hibernation of the bud moth, Wallingford, Conn., 1921*

Date of observation	Percentage of larvæ in hibernation	Date of observation	Percentage of larvæ in hibernation	Date of observation	Percentage of larvæ in hibernation
Aug. 19-----	0.0	Sept. 16-----	31.3	Oct. 5-----	95.0
25-----	14.3	19-----	31.8	10-----	96.8
Sept. 1-----	12.5	26-----	72.7	15-----	100.0
7-----	30.0	30-----	93.8		

The winter nest (Pl. II, A) is most often placed in the angle at the base of a fruit spur or a short twig, but may be constructed under a dead bud scale, in a crevice in the bark, or in any other convenient location. The hibernaculum is elongate, from 3 to 5 millimeters long and from 1 to 2 millimeters wide, and is either straight or curved, to conform to the space in which it is constructed. Included in the outer layer are bits of frass and tiny pieces of bark or bud scales, and after the nest is closed in the surface is very nearly of the color of the surrounding bark and hard to distinguish from it. The inner layers of the winter nest are of fine white silk without any foreign matter. During the construction of the hibernaculum the larva molts, as evidenced by the presence of the cast skin and head capsule, which are found at one end of the hibernaculum, usually between the outer and inner layers of silk, but sometimes visible from the outside and partially woven into the outside layer. Some larvæ are found facing away from the old cast skin, and others facing toward it.

This molt is not accompanied by the usual increase in head measurement, the average width increasing from 0.45 to only 0.50 millimeter, but the presence of the cast skin is proof that the molt has occurred.

Securely inclosed within this protecting nest, the larva passes the winter, awaiting the coming of spring and the development of the tender young foliage and succulent blossom buds.

NATURAL ENEMIES

PREDATORS

Comparatively few records seem to have been made of predacious enemies of the bud moth. Birds have been mentioned as feeding on the larvæ. Slingerland (16) reports finding the mud nests of the wasp *Odynerus catskillensis* Sauss. stored with larvæ of the bud moth and one other species. Wilson and Moznette (20) report an undetermined carabid beetle, an anthocorid bug (*Triphleps* sp.), and a mite (*Anys-tis agilis* Banks) feeding on larvæ of the bud moth.

PARASITES

Owing to the fact that the lesser bud moth, and numerous other species, have been to some extent confused with the bud moth, it

seems possible that some of the parasites said to have been reared from *Spilonota ocellana* have been in reality parasites of *Recurvaria nanella* or of some other species. More than a score of parasites are on record as having been reared from the bud moth.

EUROPEAN RECORDS

The following parasites have been recorded in Europe from the bud moth:

(*Microdus*) *Bassus dimidiator* (Nees) (11, p. 165); (*Microdus*) *Bassus rufipes* (Wesm.) (5, p. 47); *Meteorus ictericus* (Nees) (11, p. 163); *Chelonus nigrinus* Ratzb. (4, p. 43); *Chelonus similis* Nees (4, p. 42); *Bracon geniculator* Nees (6, p. 34); *Hemiteles necator* Grav. (6, p. 154) listed as a parasite of either *Spilonota ocellana* or *Tortrix varieyana*, being possibly a secondary parasite; (*Pimpla*) *Apechthis rufata* (Grav.) (6, p. 101); *Lissonota culiciformis* Grav. (10, p. 308); *Limmeria lineolata* (Ratzb.) (11, p. 163); *Mesochorus dilutus* Ratzb. (4, p. 148-149).

NORTH AMERICAN PARASITES

EGG PARASITES

Trichogramma minutum Riley was reported by DuPorte (19) from numerous localities near Quebec, destroying in some cases as many as 77 per cent of the eggs. Many specimens have also been reared in Nova Scotia (22).

One mymarid was reared from a bud-moth egg in Nova Scotia (22).

LARVAL AND PUPAL PARASITES

Secodella sp. (probably new) was reared in August, 1921, at Wallingford, Conn., from small bud moth larvæ. The same species was also reared from bud moth hibernacula in the spring of 1920 and again in the spring of 1921. This suggests the possibility of two generations of this parasite annually, one attacking the tiny bud moth larvæ soon after hatching, and the second attacking the host larvæ some time prior to hibernation. Growth of the parasite larva is completed in the late fall after the host hibernaculum is constructed, and hibernation occurs in the larval stage. Determination of these parasites was made by A. B. Gahan.

Other larval and pupal parasites have been recorded as follows:

Apanteles tnetoceræ Mues. was reared from bud moth larvæ in Nova Scotia (23 p., 560). *Opius* (*Biosteres*) sp. was reared from pupæ (19, p. 76). (*Microdus*) *Bassus carinoides* (Cress.), first reported by Riley and Howard from Canada (14, p. 18) was reared by DuPorte (19, p. 76) from pupæ of the bud moth. At Wallingford three individuals of this species were reared in 1920 and one in 1921, but in all cases the parasite larva left the host larva when the host was nearly full-grown. The Wallingford material was determined by R. A. Cushman. (*Microdus*) *Bassus laticinctus* (Cress.) was reported by Slingerland (16, p. 22) as a common parasite, reared from larvæ of the bud moth. (*Microdus*) *Bassus ocellanæ* (Rich.) was reared at Kentville, Nova Scotia (22, p. 23). *Chelonus* sp. is the most numerous parasite of the bud moth in Nova Scotia (22, p. 23). (*Pimpla*) *Itoplectis conquisitor* (Say) was reared from bud moth pupæ in Quebec (19, p. 76.) (*Pimpla*) *Epiurus* near *alboricta* Cress. was recorded by Slingerland (16, p. 22) from larvæ in July, 1892. A single individual of *Epiurus indagator* (Walsh) was reared at Wallingford, Conn., in 1920, and another in 1921 from fifth-stage larvæ. It was determined by R. A. Cushman. *Phylodictus* [*Phylodictus*] *vulgaris* Cress. was recorded by Fernald (15, p. 9) as an external feeder on host larvæ. *Anomalon*

sp. was reported from Nova Scotia (22, p. 23). Two individuals of *Winthemia quadripustulata* (Fab.) were reared at Wallingford from pupæ from bud moth larvæ which were collected in the field when nearly full-grown. They were determined by Dr. J. M. Aldrich.

CONTROL

A study of the life history of the bud moth suggests as the most favorable opportunity for its control the spring feeding period, as during this time the larvæ feed to a considerable extent on exposed leaf tissue.

During the hibernating period the larva is protected by a compactly woven silken shelter, and even the strong solutions used in dormant spraying are not likely to penetrate to the larva. Scott and Paine (18) report that applications of lime-sulphur and soda-sulphur solutions at dormant strength had no effect on the larvæ of the lesser bud moth while they were still in their hibernacula. Working with the bud moth, Wilson and Moznette (20) found that oils applied during the dormant season had no effect on the protected larvæ. In December, 1921, at the Wallingford station, a small number of twigs bearing hibernacula were dipped in the solutions usually used for dormant apple spraying: Lime-sulphur 1 to 9, the same with the addition of nicotine sulphate 1 to 800, and a miscible oil 1 to 15. This was done on a warm day, and the twigs were placed out of doors under normal conditions. Examination two weeks later showed that none of the larvæ had been affected by the treatment. The experimental evidence just cited is sufficient to indicate that little is to be expected from dormant applications.

For the control of the lesser bud moth, the so-called delayed dormant application of lime-sulphur, put on as the buds are showing a small amount of green, was effective, presumably acting as a repellent, keeping the newly emerged larvæ from entering the buds. With the bud moth, however, emergence from hibernation occurs a few days too late for the effective use of this treatment, as in Connecticut, at least, few of the larvæ leave winter quarters before the leaves have begun to unfold. DuPorte (21) reports a similar observation in Quebec.

Experiments were conducted on a limited scale at Wallingford with applications at the time when the apple blossoms showed pink, and again at the time of the usual calyx application.

On April 21, 1921, about the time the blossom buds were showing pink, a number of infested apple twigs were brought in; 23 of them were sprayed with powdered arsenate of lead, 1 pound in 50 gallons, and 17 were left as checks. After being sprayed the twigs were placed in water, to keep them fresh, and examined on April 27. At the time of this experiment the characteristic bud moth nests had not been made, and a number of lesser bud moth larvæ were included. The results are given in Table 6.

TABLE 6.—*Results of experiments in spraying apple twigs infested with the bud moth and the lesser bud moth with powdered arsenate of lead at the time the blossom buds were showing pink*

Treatment	Number of larvæ		
	Healthy	Sickly	Dead
Sprayed (23 twigs):			
Bud moth.....	0	2	0
Lesser bud moth.....	6	3	2
Check (17 twigs):			
Bud moth.....	6	0	0
Lesser bud moth.....	9	0	0

It is quite possible that some larvæ were killed by the spray, but left the foliage before dying.

On May 11, at the time of the calyx application, and some time before any larvæ had made preparations for pupation, a similar experiment was carried out. The material was examined on May 18, and the results are noted in Table 7.

TABLE 7.—*Results of calyx application on apple twigs infested with the bud moth*

Treatment	Number of larvæ		
	Healthy	Sickly	Dead
Sprayed (19 twigs).....	6	5	4
Check (18 twigs).....	10	0	0

In both of these tests more larvæ would undoubtedly have died if more time had elapsed before the material was examined, but the foliage was beginning to wilt, and the examination could not be further delayed. The presence of dead larvæ in the second test, however, indicated that the arsenate of lead was being consumed and was having its effects.

During the same season a number of small apple trees of several varieties in a near-by orchard were sprayed with arsenate of lead, 1 pound in 50 gallons, using a bucket pump. Each plat contained from 9 to 12 trees. One plat received the pink application only, one the calyx application only, and a third received both applications. Later on, before any larvæ had begun to pupate, all nests were removed from four count trees in each plat, and the numbers of dead, sickly, and healthy larvæ were recorded. The results are given in Table 8.

TABLE 8.—*Effect of arsenate of lead spray on small apple trees infested with the bud moth*

Plat	Treatment	Nests found	Larvæ found		
			Healthy	Sickly	Dead
I.....	Pink and calyx.....	51	3	2	5
II.....	Pink alone.....	58	11	1	0
III.....	Calyx alone.....	122	8	4	16
IV.....	Check.....	123	38	0	1

Although the experiments outlined above were conducted on a comparatively small scale, the results indicate very clearly that the arsenical sprays applied while the larvæ are feeding in the spring will kill a large percentage of them. In the field tests summarized in Table 8, a single application when the blossoms were showing pink apparently reduced the number of healthy larvæ present 71 per cent, a single application just after the petals had fallen reduced the number 79 per cent, and where both were applied the number of healthy larvæ was reduced 92 per cent. On the trees receiving the earlier application the number of nests was less than half the number found on trees receiving only the calyx application or none at all. The calyx spray comes too late to prevent much of the current season's injury, but kills a large proportion of the larvæ, and reduces the numbers of the next generation which is to feed during the summer and the following spring. No experiments were made with dusting, but a careful treatment with dust would probably be about as effective with this species as the liquid.

These results bear out for the most part those reported by the most recent workers on the bud moth. DuPorte (21) reports the combined efficiency of the two pre-blossom sprays and the calyx spray to be 86.5 per cent, and the efficiency of the pink and calyx treatments combined to be 80 per cent. Sanders and Dustan (22) report that the two most efficient spray applications for bud moth control (referring in general to the four species discussed) are: One when the leaves are the size of a dime, and a second immediately before the blossoms open. Further confirmation of the results noted above will be found in the fact that well sprayed orchards, which always receive the calyx application, and usually the pink cluster-bud spray, are seldom seriously troubled by the bud moth.

In case of a severe infestation, in addition to the pink and calyx applications it would probably be advisable to put on an arsenical spray about midway between the delayed dormant and pink applications, in order to keep the rapidly growing foliage as well coated as possible with the poison.

The hatching of the eggs extends over a period of a month or more, beginning about the middle of July under average Connecticut conditions. The tiny larvæ feed on the foliage and to a certain extent on the fruit during the remainder of the summer, but their feeding areas are small and for the most part confined to the lower surfaces of the leaves and under the shelter of a web of silk, or in protected places where fruit and leaves are in contact. Some success has been reported with the use of arsenicals against the young larvæ during this period, but in view of the fact that the bud moth may be controlled satisfactorily by the routine spring applications, the later treatments will probably seldom be necessary. If a single summer application is to be made, it will be best to wait until nearly the end of the hatching period, which would be early in August under Connecticut conditions. Care must be taken to cover with the spray the lower surfaces of the leaves, where the majority of the larvæ feed.

SUMMARY

The bud moth, *Spilonota ocellana*, which is presumably a European insect, was first noted in this country about 1841, and has become an important apple pest. It is now present over much of the northern part of the United States and southern Canada.

This species is a rather general feeder, attacking most of the deciduous fruit trees and some ornamental, shade, and forest trees.

At least five other species (the lesser bud moth, *Recurvaria nanella*, the oblique-banded leaf-roller, *Cacoecia rosaceana*, the green bud-worm, *Olethreutes consanguinana*, *Olethreutes chionosema*, and the leaf-crumpler, *Mineola indigenella*) winter in a similar manner, and are likely at one time or another to be confused with the bud moth.

The tiny brown larvæ emerge from hibernation for the most part as the leaves are unfolding, and feed in the expanding foliage and blossom buds. After a few days of feeding, they make nests, usually in a leaf, which later becomes dead and brown, and feed principally outside the nests. After several molts the larvæ cease feeding and construct cocoons, sometimes in the old nest, and in other cases in a new place, where they transform to brown pupæ. After a period lasting from 12 to 21 days they emerge as moths, which after a few days deposit their tiny, flattened, oval, translucent white eggs on the foliage. After 7 to 10 days these eggs hatch. The tiny larvæ are at first white, but in a few days become a dirty yellow, and later brown. The greater number of these larvæ feed on the foliage, usually on the under side of the leaf next the midrib or a large vein, constructing tubular shelters and feeding under the protection of a rooflike silken web. Other larvæ feed on the fruit, usually where it is in contact with a leaf, making small blemishes. After feeding for several weeks and molting two or three times, the tiny worms leave the foliage and construct winter shelters in crevices in the bark, under bud scales, and in other more or less concealed places. During the construction of the hibernaculum the larva molts.

Numerous parasites have been reared from the bud moth, both in North America and in Europe.

A satisfactory degree of control is usually obtained by two of the usual routine spring spray applications—the pink cluster-bud application (to which arsenate of lead, 1 pound of the dry form in 50 gallons of water, should be added), and the calyx spray, which is applied primarily for codling moth control. In exceptionally severe infestations, an arsenical should also be applied about midway between the bursting of the buds and the time when the blossom buds will show pink. An arsenical application in August will seldom be necessary, but if one is carefully applied, and the under surfaces of the leaves are covered with poison, additional protection will be secured.

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UNITED STATES DEPARTMENT OF AGRICULTURE



DEPARTMENT BULLETIN No. 1303



Washington, D. C.



April, 1925

THE PECAN NUT CASE-BEARER¹

By JOHN B. GILL, Associate Entomologist, Fruit Insect Investigations, Bureau of Entomology

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INTRODUCTION

For a number of years the Bureau of Entomology maintained a field laboratory in the southeastern portion of the pecan belt at Monticello, Fla., for the investigation of the biology and habits of pecan insects and to determine the most effective control measures for the more important species under orchard conditions. The results of the greater portion of these investigations have been published (4, 5),² but as a part of this work this bulletin brings together the results of a rather detailed study of the life history of the pecan nut case-bearer (*Acrobasis hebescella* Hulst), an insect which is now recognized as a most formidable enemy of the pecan because of its nut-feeding habits.

HISTORY

The pecan nut case-bearer was first described by Hulst (7) in 1890 under the name of *Acrobasis hebescella*. In 1893 Ragonot (9) treated this species, and in 1901 it was listed and figured by Hampson (6), but the figure given is a poor reproduction of the moth. Dyar's "List of North American Lepidoptera" (1) contains this species, the distribution being given as New Jersey, Texas, Illinois, and Wisconsin. In 1902 E. P. Stiles (11) gave an account of injury in west-central Texas caused by what he called the pecan huskworm, but doubtless due to *Acrobasis hebescella* and a closely related species, *A. caryvorella* Rag.

¹ *Acrobasis hebescella* Hulst; order *Lepidoptera*, family *Pyrallidae*.

² Reference is made by number (italic) to "Literature Cited," p. 12.

Sanderson (10) reported serious injury to the pecan crop by *A. caryae* in 1903, but it appears to the writer that the greater portion of the damage, if not all, should have been accredited to the species of *Acrobasis* discussed in this bulletin and to *A. caryivorella*. Dyar in 1908 (2), in a paper on the species of *Acrobasis*, includes this insect. In 1914 the writer (3) made a brief mention of this species in an article on the pecan leaf case-bearer (*Acrobasis nebulella* Riley), and in Farmers' Bulletin 843 (4), appearing in 1917, it is treated at length. The following year Turner (12) and Matz (8) gave general accounts of the insect.

DISTRIBUTION

Hulst (7), in his original description of *Acrobasis hebesella*, gave New Jersey and Texas as its habitat; Dyar (1) listed it from New Jersey, Texas, Illinois, and Wisconsin, and in an article appearing in 1908 (2) mentioned Brownwood, Tex., and East River, Conn., as localities in which it has been collected; and Turner (12) reported it from Thomasville, Ga., and Cairo, Ga. In the United States National Museum collection there are specimens from Brownwood, Tex.; Goodman, Miss.; Bon Ami, La.; and Monticello, Fla. Besides the localities mentioned, the records of the writer show that this species also occurs at Waukeenhah, Fla.; Baconton, Dewitt, Putney, and Moultrie, Ga.; Mobile and Fowl River, Ala.; Ocean Springs and Pecan, Miss.; Keithville, La.; and Marshall, Victoria, and Bend, Tex.

The pecan nut case-bearer, along with another nut-feeding species of *Acrobasis*, *A. caryivorella* Rag., is rather generally distributed in the pecan-growing sections of the Southwest, especially in Texas, where it is reported annually as causing much damage. In the Southeast, however, it has been recorded only from scattered localities in Florida, Georgia, Alabama, Mississippi, and Louisiana. For the last 9 or 10 years this insect has been causing considerable loss to pecan growers in the vicinity of Monticello, Fla., and Thomasville, Ga., and during 1922 it was reported for the first time as occurring in injurious numbers in the large commercial orchards in the Albany, Ga., district, which is at present rated as the most important section for the production of cultivated pecan nuts. In 1923 and 1924 the insect caused very heavy damage in the large orchards at Baconton, Dewitt, Putney, and Albany, all in this district. This species appears to be gradually extending its range of destructiveness, and sooner or later it will probably prove a most formidable pest throughout the greater portion of the pecan belt.

FOOD PLANTS

The only food plant on which this insect has been found by the writer is the pecan (*Hicoria pecan*), but it is to be supposed that it subsists also on other species of the genus *Hicoria*. In literature oak and pecan are given as food plants. Dyar (2) states that six specimens from Brownwood, Tex., were bred at the insectary of the U. S. Department of Agriculture from larvæ on pecan mining into the young buds. In his original description Hulst (7) has the following statement:

A specimen from New Jersey received by Prof. J. B. Smith, has on it a label marked "on oak, Jersey pines, June." The pin is thrust through an oval close cocoon which was undoubtedly made at or under the surface of the ground.

He further states:

I have myself found the larval cases of a Phycitid in southern New Jersey on a large-leaved oak, which may be the cases of this species. They were horn-like, much resembling those of *indigenella*. The larva turned over the edge of the large leaf binding the edges, and forming a habitation large enough to move about freely within. The case itself was fastened within with threads of silk.

The habitat given by Hulst is New Jersey and Texas, but there is no mention of the food plant for the material from Texas, which was probably taken on the pecan. In the writer's opinion, the record of the New Jersey specimen "from oak" is very doubtful, because the description of the cocoon and the manner of pupation do not coincide with the facts regarding *Acrobasis hebesella* as determined in an extensive study of this species.

CHARACTER OF INJURY

The larvæ of the pecan nut case-bearer may attack either the tender shoots or the immature nuts. The larvæ that pass the winter in hibernacula around the buds cause damage in early spring by attacking the tender shoots, in which they tunnel and eat out the interior, leaving the outside intact. Many of the attacked shoots wilt and turn brown, and others are broken off by the winds (Pl. IV). Such injury is not very serious, compared with the damage caused by the first and second brood larvæ, which confine their attacks to young green nuts.

During May the first-brood larvæ make their appearance and bore into the recently set nuts. At the point of attack pellets of frass or borings are cast out (Pl. II) and held together by means of fine silken threads that form a short silk-lined tube. Nuts injured by this insect always show the characteristic mass of frass protruding from the place where the larvæ gained entrance, which is invariably in the side of the nut near the basal end. The larvæ of the second generation attack the nuts in the same manner as those of the first generation, but the damage to the crop is not so extensive because of the size of the nuts at the time of attack (Pl. III). Early in the season a single larva may destroy several nuts before attaining full growth, while later in the season one or two nuts seem to be sufficient for its subsistence. The writer's observations show that by far the greatest damage to the nut crop is inflicted by the larvæ of the first generation.

The larvæ of the third generation, which make their appearance in the late summer, usually feed very little. They seem to prefer the shucks or hulls, in which they gnaw only through the surface, forming small, narrow, elongated tunnels of frass particles of a rather delicate or flimsy texture. Such injury does not interfere with the normal development of the nuts. Some of these larvæ also feed slightly on the leaf petioles and succulent shoots, but the damage thus caused is insignificant. When the larvæ of this generation seek hibernation quarters they are usually a little less than one-tenth of an inch long.

DESCRIPTION

EGG

The egg (Pl. I, A) is elliptical, convex above and flattened below, with the surface finely wrinkled. When first deposited the egg is greenish white, and as incubation advances it takes on a reddish

tinge. The eggs average 0.56 millimeter in length by 0.34 millimeter in width. The moths deposit their eggs singly on the calyx end of the nut or on the side of the nut under the calyx lobes.

LARVA

The larva (Pl. I, B at right, and D) is nearly cylindrical, tapering slightly toward each end, but more posteriorly than anteriorly. Eight full-grown larvæ when extended averaged 14.59 millimeters in length by 2.08 millimeters in greatest width. The head and mouth parts are dark brown, and the prothoracic shield is pale brown, bisected by a rather inconspicuous faint whitish area. The general color of the body is dirty olive green, darker dorsally and laterally than ventrally. The body is sparsely covered with fine whitish hairs, the skin being quite wrinkled, especially in the thoracic region. The thoracic legs are about the same color as the ventral part of the body, and each terminates in a single brown claw. There are five pairs of prolegs and the anal pair is about twice as long as the others.

PUPA

The pupa (Pl. I, B, at left) is of the usual form and without striking markings. When first formed it has a decided olive-green cast, but with age it changes to a light brown. The abdominal segments are finely punctate, the anterior portion of the last segment having a dark brown transverse band dorsally. The anal extremity is armed with a short, sharp brownish tooth, directed nearly at right angles to the body axis, and four slender light-brown hooked spines, which arise from the lower part of the tip of the last segment and project forward. The size of the pupa is decidedly variable, the average measurements for six individuals being 8.1 millimeters by 2.2 millimeters. The pupa is formed inside the attacked shoot for the spring brood (Pl. IV), and within the infested nut for the first and second broods (Pl. I, E). Upon issuance of the moth the pupal skin is not extended.

ADULT (Pl. I, C)

The pecan nut case-bearer was first described in 1890 by Hulst (?) under the name *Acrobasis hebescella*. The original description is as follows:

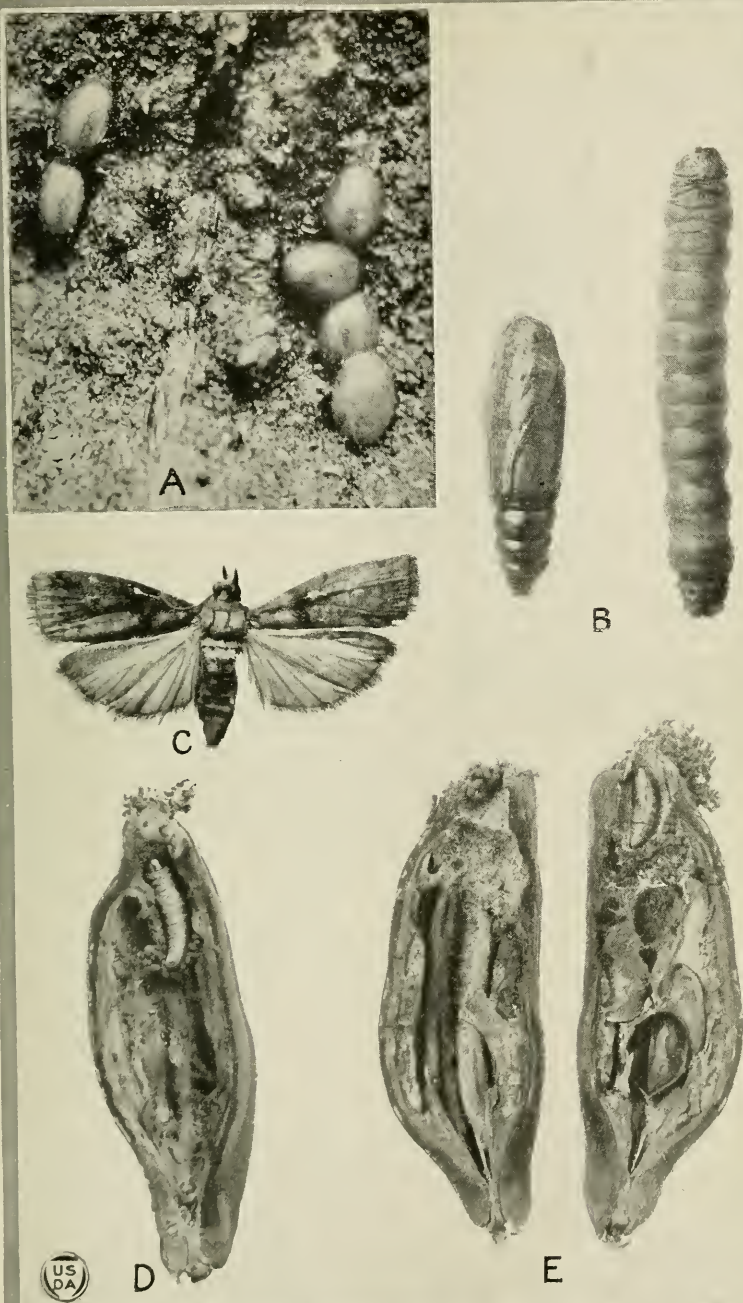
Expands 18-20 mm. Labial palpi blackish gray. Head ochreous fuscous, thorax dark fuscous. Abdomen ochreous gray, annulate with fuscous. Fore wings short, very broad, strongly arched on costa and inner margin, ochreous fuscous, quite dark; lines indistinct, basal hardly discernible, faintly gray, edged outwardly with black at costa; scale ridge black, short; outer line dentate, shown by black border lines on ground color; discal spots quite distinct, confluent. Hind wings dark even fuscous.

The measurements of moths bred from pecans varied from 14.5 to 19 millimeters across the expanded wings.

SEASONAL HISTORY AND HABITS

All records given for the various stages of the pecan nut case-bearer were obtained at Monticello, Fla. In the rearing work pertaining to this insect glass jars were used as cages, which were kept in an open-air insectary.

In the discussion of the life history of this species, a "generation" is considered to begin with the egg stage and to end with the adult or



THE PECAN NUT CASE-BEARER

A, Eggs on nut. Greatly enlarged. B, Pupa at left larva at right. Enlarged. C, Adult, or moth. Enlarged. D, Immature pecan nut infested by larva. Slightly enlarged. E, Infested pecan nut showing place of pupation. Slightly enlarged



IMMATURE PECAN NUTS, SHOWING INJURY. NATURAL SIZE



CLUSTERS OF INFESTED PECAN NUTS. NATURAL SIZE



PECAN SHOOTS, SHOWING INFESTATION BY LARVAE IN THE SPRING. REDUCED

moth stage. The term "brood" is used in speaking collectively of the individuals of any stage of a particular generation, as egg, larva, pupa, or adult. The overwintering larvæ, after transforming in the spring to pupæ and in turn to adults are referred to as "spring-brood pupæ" and "spring-brood moths." Although the spring-brood pupæ and moths are the first to make their appearance during the growing season, they are not designated as first-brood pupæ and first-brood moths, but these terms are reserved for the pupæ and moths of the next succeeding generation.

ADULT AND EGG STAGES

TIME OF EMERGENCE OF THE SPRING-BROOD MOTHS

From material under observation during the season of 1916 it was determined that spring-brood moths emerged from May 7 to May 23, and in 1917 the period of emergence was May 2 to May 17. Moths in the pecan orchard evidently came forth about the same time as those in rearing cages, a fact which was determined by numerous field observations. There is, however, one record of collecting an empty pupal skin in the field as early as May 1, 1917, indicating that this particular individual emerged earlier than the first insectary rearing. The dates of issuance of 60 individuals are shown in Table 1.

TABLE 1.—*Time of emergence of spring-brood moths of the pecan nut case-bearer, Monticello, Fla., 1916 and 1917*

1916				1917			
Date of emergence	Number of moths	Date of emergence	Number of moths	Date of emergence	Number of moths	Date of emergence	Number of moths
May 7.....	1	May 16.....	5	May 2.....	1	May 12.....	2
8.....	1	17.....	5	3.....	5	14.....	1
10.....	1	18.....	3	4.....	3	16.....	3
11.....	2	19.....	3	5.....	1	17.....	3
12.....	1	20.....	1	7.....	1		
13.....	5	23.....	1	10.....	4	Total.....	24
14.....	1						
15.....	6	Total.....	36				

TIMES OF EMERGENCE OF FIRST AND SECOND BROOD MOTHS

Records on the times of emergence of first and second brood moths are given in Table 2 for 1914, 1915, 1916, and 1917.

From material under observation during the season of 1914, it was determined that first-brood moths emerged from June 11 to July 2, covering a period of 22 days. The maximum emergence occurred on June 23, when 15 moths came forth. The second-brood moths began to appear on July 23 and continued emerging until August 26; a period of 35 days for all individuals under observation. Probably the times of emergence of both the first and second brood moths varied somewhat from the dates based on reared specimens, but no doubt the data given closely approximate the actual times of emergence under natural conditions.

The records for 1915 show that the first-brood moths emerged from June 18 to July 15, the maximum emergence of 13 individuals occur-

ring on June 24 and emergence for all moths extending over a period of 28 days. The earliest record of emergence for the second-brood moths occurred August 2 and emergence continued until August 31, a period of 30 days.

The emergence of the first-brood moths for 1916 began June 17 and lasted until July 16, covering a 30-day period. For the second-brood moths emergence took place from August 3 to August 30, a period of 28 days.

For 1917 the first-brood moths were found to emerge from June 13 to July 12, covering a period of 30 days. The greatest number to appear on a single day was 16 on June 29, while June 23 to July 2 marked the period of maximum emergence. The second-brood moths emerged from August 2 to August 30, a 29-day period for emergence.

TABLE 2.—*Times of emergence of the first and second brood moths of the pecan nut case-bearer, Monticello, Fla., 1914, 1915, 1916, and 1917*

First brood					Second brood				
Date	1914	1915	1916	1917	Date	1914	1915	1916	1917
	Number	Number	Number	Number		Number	Number	Number	Number
June 11.....	2				July 23.....	1			
12.....	2				24.....	3			
13.....	1			1	25.....	4			
14.....				6	26.....	4			
15.....	5			1	27.....	4			
16.....	5			1	28.....	9			
17.....	2		1	1	29.....	5			
18.....	2	2	4	2	30.....	9			
19.....	14		2	3	31.....	5			
20.....	6	2	4	1	Aug. 1.....	3			
21.....	8	2		4	2.....	4	1		1
22.....	7	4	3	3	3.....	9		1	
23.....	15	2	5	10	4.....	10	1	1	
24.....	12	13	5	12	5.....	6	2		
25.....	10	10	2	6	6.....	1	2		
26.....	5	5	8	14	7.....	6	6	1	
27.....	8	5	5	6	8.....	8		1	2
28.....	2	4	6	9	9.....	1	11		
29.....	2	3	3	16	10.....	8	7		1
30.....	1	2	7	5	11.....	10	5	1	1
July 1.....	1	1	6	7	12.....	12	10	3	
2.....	2	1	10	14	13.....	6	6	2	3
3.....		2	8	1	14.....	4	4		3
4.....		4	9	4	15.....	9	3	1	1
5.....		2	2	1	16.....	1	1	1	
6.....			3	3	17.....	5	7	3	1
7.....		1	1	4	18.....	4	3	6	1
8.....			2		19.....	4	9	5	1
9.....		2	1	2	20.....	8	8	3	
10.....					21.....		5	2	1
11.....			1	3	22.....		7	1	1
12.....				1	23.....		4	2	3
13.....		1	1		24.....	2	4	1	1
14.....					25.....		3		1
15.....		2			26.....	1	3	2	2
16.....			1		27.....		1	2	2
					28.....		1	2	2
					29.....				1
					30.....			1	1
					31.....		1		
Total.....	112	70	100	141	Total.....	166	116	42	30

LENGTH OF LIFE OF MOTHS

The length of life of moths varied from 2 to 15 days, the average for those under observation being about 6 days. The data bearing on this phase of the life history are insufficient to make any generalization, as only a few observations were made to determine this point.

OVIPOSITION AND LENGTH OF INCUBATION PERIOD

It was very difficult to get moths to oviposit in confinement. From material under observation it was determined that a period of from 2 to 7 days elapsed from the time of emergence to the time of first oviposition. The moths confined in cages usually deposited all eggs within a period of 3 days. In confinement moths deposited eggs indiscriminately upon the nuts, leaf petioles, foliage, and occasionally on the sides of the glass breeding jars. It seems that under natural conditions egg deposition invariably takes place on the nuts at the calyx or on the side immediately under the calyx lobes.

As is shown in Table 3, the average length of the period of incubation of 56 first-brood eggs was found to be 9.48 days, the maximum being 10 and the minimum 7.

TABLE 3.—Length of incubation period of first-brood eggs of the pecan nut case-bearer, Monticello, Fla., 1917

Number of eggs from which larvæ emerged	Date of oviposition	Date of hatching	Length of incubation period
29	May 11---	May 21---	Days 10
26	13---	22---	9
1	15---	22---	7

The length of the incubation period for second-brood eggs is given in Table 4.

TABLE 4.—Length of incubation period of second-brood eggs of the pecan nut case-bearer, Monticello, Fla., 1916 and 1917

1916				1917			
Number of eggs from which larvæ emerged	Date of oviposition	Date of hatching	Length of incubation period	Number of eggs from which larvæ emerged	Date of oviposition	Date of hatching	Length of incubation period
			Days				Days
11	June 26-----	July 1-----	5	41	July 1-----	July 7-----	6
3	do-----	July 2-----	6	14	do-----	July 8-----	7
4	June 27-----	July 3-----	6	6	July 5-----	July 10-----	5
1	June 28-----	July 4-----	6	45	do-----	July 11-----	6
8	July 3-----	July 8-----	5	12	do-----	July 12-----	7
1	do-----	July 10-----	7	2	July 6-----	do-----	6
8	July 14-----	July 18-----	4	3	do-----	July 13-----	7
9	do-----	July 19-----	5	13	July 7-----	do-----	6
2	do-----	July 20-----	6				
Average for 47 individuals-----			5.09	Average for 136 individuals-----			6.17

Observations on a limited number of third-brood eggs hatching in August showed that the period of incubation ranged from 4 to 6 days, the average being 4.95 days.

LARVA STAGE

EMERGENCE OF LARVÆ FROM HIBERNATION

The overwintering larvæ become active and leave their winter cases (hibernacula) during the latter part of March or the first part of April, at which time the buds on pecan trees begin to open. After feeding slightly upon the unfolding buds, these spring-brood larvæ migrate to the rapidly growing succulent shoots, in which they feed by tunneling out the interior, keeping the burrows open by casting out the frass pellets from the hole where the initial attack was made (Pl. IV). It has been determined from field observations that the larvæ usually begin to attack the pecan shoots during the second week in April, and after feeding in this manner for two weeks or more the larvæ transform to pupæ within their burrows. During 1916 the spring-brood larvæ that were under observation pupated from April 24 to May 12, and in 1917 from April 19 to May 1. Records show, however, that a few larvæ can be found on pecan trees, especially the Stuart variety, as late as the second week in May.

FIRST-BROOD LARVÆ

The length of larval life for the first brood ranges from 22 to 29 days, the average being about 26 days. The maximum hatching of first-brood larvæ occurs during the third week in May, but the period of hatching is quite extended.

SECOND-BROOD LARVÆ

The majority of the second-brood eggs hatch during the last week in June and the first 10 days of July, but the hatching for all eggs of this brood extends over a long period. The average length of the larva stage for the second brood was found to be 25.27 days.

THIRD-BROOD LARVÆ

The hatching of third-brood larvæ begins about the middle of August and continues until the first part of September. The latest hatching of third-brood larvæ in rearing cages occurred on September 3, but under natural conditions it is likely that larvæ hatch over a longer period. The third-brood larvæ feed very sparingly for three or four weeks and then go into hibernation by constructing hibernacula, which are attached to the buds. Although the larvæ feed for several weeks, they do not attain a size greater than one-tenth of an inch. In rearing work it has been observed that the larvæ are very prone to construct their hibernacula prematurely when the food plant in breeding cages is not kept in the best of condition. The larvæ remain in their hibernacula throughout the winter, and with the advent of spring they become active just as the buds on the pecan trees are unfolding.

PUPA STAGE

PLACE OF PUPATION OF THE OVERWINTERING LARVÆ

The spring-brood pupæ are formed within the shoots in which the larvæ complete their growth. Near the mouth of its burrow the full-grown larva prepares out of particles of frass and excrement a flimsy silken-lined cell or cocoon, where its transformation to the pupa stage occurs (Pl. IV).

TIME OF PUPATION OF OVERWINTERING LARVÆ AND LENGTH OF SPRING-BROOD PUPAL PERIOD

Investigations show that the time of pupation of the overwintering larvæ is variable. Records for 1916 give April 24 as the earliest date of pupation, and the latest as May 12; while for 1917 pupæ were forming in rearing cages from April 19 to May 1. During the season of 1917 overwintering larvæ were observed in the field after May 1, showing that insectary records do not actually indicate the complete period at which transformation to pupæ occurs. Before making any generalization on the time of pupation, more extensive data are desirable, as observations have been confined to a limited number of individuals.

During 1916 and 1917 the length of the pupal period of the spring brood was determined for 19 individuals, as shown in Table 5:

TABLE 5.—Length of pupal period of spring-brood pupæ of the pecan nut case-bearer, Monticello, Fla., 1916 and 1917

1916				1917			
Num- ber of indi- viduals	Date of pupation	Date of emergence	Days as pupa	Num- ber of indi- viduals	Date of pupation	Date of emergence	Days as pupa
1	Apr. 24.....	May 11.....	17	1	Apr. 19.....	May 2.....	13
1	Apr. 28.....	May 13.....	15	1	Apr. 20.....	May 3.....	13
1	May 2.....	May 14.....	12	1	Apr. 28.....	May 14.....	16
1	May 4.....	May 15.....	11	1	do.....	May 16.....	18
1	May 5.....	May 16.....	11	1	Apr. 29.....	May 17.....	18
2	May 6.....	May 17.....	11	1	Apr. 30.....	do.....	17
2	May 7.....	May 18.....	11	1	May 1.....	May 16.....	15
1	do.....	May 19.....	12				
1	May 8.....	do.....	11				
1	May 12.....	May 23.....	11				
Average for 12 individuals.....			12	Average for 7 individuals.....			15.85

TIME OF PUPATION AND LENGTH OF PUPAL PERIOD OF THE FIRST AND SECOND BROOD PUPÆ

Of the first-brood larvæ under observation that transformed to pupæ during 1914 the first pupated June 9, and during 1916 and 1917 the first pupæ appeared June 5 and June 2, respectively. Pupation continued in 1916 until June 29 and in 1917 until July 2, while in 1914 the last pupa for insectary material was recorded on June 19. It should be stated, however, that larvæ under natural conditions were probably pupating for a week or 10 days later than pupation records for 1914 indicate, as it was determined on June 20 from field-collected material that only 85 per cent of the larvæ had pupated. These records are given in Table 6.

The second-brood larvæ transform to pupæ during the latter half of July and the greater part of August. The time of pupation for a number of individuals of the second brood is also given in Table 6. These records, however, do not represent the entire period of pupation for the second brood, as only a limited number of transforming larvæ were under observation during some seasons.

TABLE 6.—*Length of pupal period of the first and second brood pupæ of the pecan nut case-bearer, Monticello, Fla., 1914, 1915, 1916, and 1917*

Number of individuals	Date of pupation	Date of emergence	Days as pupa	Number of individuals	Date of pupation	Date of emergence	Days as pupa
1914—FIRST BROOD				1916—FIRST BROOD—Continued			
1	June 9	June 19	10	1	June 8	do	11
1	June 10	June 22	12	2	June 9	do	10
1	June 12	June 21	9	1	do	June 20	11
2	do	June 23	11	1	June 11	June 22	11
1	June 13	June 25	12	1	June 17	June 28	11
5	June 15	June 24	9	1	do	June 30	13
1	do	June 26	11	1	June 18	do	12
3	June 16	June 27	11	2	do	July 1	13
4	June 17	do	10	1	June 19	July 2	13
1	do	June 28	11	1	June 20	July 3	13
1	June 18	do	10	2	June 21	do	12
1	June 19	June 29	10	1	June 24	July 4	10
Average for 22 individuals			10.23	1	do	July 5	11
1914—SECOND BROOD				1	June 26	July 7	12
1	July 13	July 23	10	1	do	July 8	11
1	do	July 24	11	1	June 27	do	11
2	do	July 25	12	1	June 28	July 9	11
1	July 14	July 24	10	1	June 29	July 11	12
2	do	July 25	11	Average for 24 individuals			11.58
3	do	July 26	12	1916—SECOND BROOD			
2	July 15	do	11	2	Aug. 8	Aug. 17	9
2	do	July 27	12	2	do	Aug. 18	10
1	July 16	do	11	2	do	Aug. 19	11
1	do	July 28	12	1	Aug. 9	do	10
4	July 18	do	10	1	Aug. 10	Aug. 20	10
1	July 19	July 29	10	1	Aug. 15	Aug. 24	9
1	July 20	do	9	1	do	Aug. 26	11
1	do	July 30	10	1	Aug. 17	Aug. 28	11
3	do	July 31	11	Average for 11 individuals			10.09
2	July 21	do	10	1917—FIRST BROOD			
1	July 23	Aug. 2	10	1	June 2	June 13	11
1	do	Aug. 3	11	1	June 3	June 14	11
1	July 27	Aug. 7	11	1	June 7	June 18	11
1	July 28	Aug. 8	11	1	June 8	June 21	13
1	July 29	Aug. 9	11	3	June 9	do	12
1	do	Aug. 11	13	2	June 12	June 24	12
1	Aug. 3	Aug. 13	10	1	do	June 25	13
1	Aug. 5	Aug. 16	11	2	June 13	June 26	13
1	do	Aug. 17	12	3	June 14	do	12
1	Aug. 12	Aug. 24	12	1	do	June 27	13
1	Aug. 13	Aug. 26	13	1	June 15	do	12
Average for 39 individuals			11	1	do	June 28	13
1915—SECOND BROOD				1	June 16	do	12
1	July 25	Aug. 3	9	1	June 17	do	11
1	do	Aug. 4	10	2	do	June 29	12
1	July 26	Aug. 5	10	1	June 18	do	11
2	July 31	Aug. 10	10	1	June 20	July 2	12
3	do	Aug. 11	11	1	June 21	do	11
4	do	Aug. 12	12	1	June 23	July 4	11
1	do	Aug. 13	13	2	June 25	July 6	11
4	Aug. 1	Aug. 12	11	2	do	July 7	12
2	do	Aug. 13	12	1	June 29	July 11	12
6	Aug. 2	do	11	1	July 2	July 12	10
1	do	Aug. 14	12	Average for 32 individuals			11.84
1	Aug. 3	Aug. 15	12	1917—SECOND BROOD			
2	Aug. 4	Aug. 13	9	2	Aug. 1	Aug. 13	12
3	do	Aug. 14	10	2	Aug. 2	Aug. 14	12
Average for 32 individuals			10.91	1	Aug. 14	Aug. 27	13
1916—FIRST BROOD				1	Aug. 19	Aug. 30	11
1	June 5	June 17	12	Average for 6 individuals			12
1	June 7	June 18	11				
1	do	June 19	12				

The data on the length of the pupal period of the first-brood pupæ for 1915 are incomplete, but in the case of the few individuals under observation the pupal period lasted from 10 to 11 days.

NUMBER OF GENERATIONS

Life-history studies have shown that under normal conditions the pecan nut case-bearer has three generations annually, at Monticello, Fla., and that it passes the winter in the immature larva stage of the third generation. These third-brood larvæ after feeding sparingly for a few weeks migrate during the latter part of September or the first part of October to the buds, where they construct small, compactly woven hibernacula, in which they hibernate until the following spring, when the buds on pecan trees are beginning to open. In confinement it may be possible for the pecan nut case-bearer to have four generations.

PARASITIC ENEMIES

The writer has on several occasions reared a number of parasitic insects from the larvæ and pupæ of the pecan nut case-bearer as follows: *Exorista (Nemorilla) pyste* Walk.,³ *Habrobracon variabilis* Cush.,⁴ *Calliephialtes grapholithæ* Cress.,⁴ *Cremastus (Zaleptopygus)* sp.,⁵ and *Angitia* sp.⁴ The most effective parasite is the tachinid fly *Exorista pyste* Walk., which was reared in large numbers from the larvæ and pupæ, and is no doubt a very important factor in the natural control of this pest. The braconid *Habrobracon variabilis* also was frequently bred, and is perhaps second in importance among the parasites of the pecan nut case-bearer.

CONTROL MEASURES

Investigations so far conducted show that the best method of control against the pecan nut case-bearer is spraying with arsenate of lead.⁶ The arsenate should be used at the rate of 1 pound of the powdered form, or 2 pounds of the paste form, to each 50 gallons of water, to which should be added the milk of lime from 3 pounds of slaked lime. The addition of lime is necessary to prevent arsenical injury to the foliage and nuts. Three applications will be required and should be at the following periods:

1. Soon after the nuts have set, at which time they are about the size of garden peas.
2. One week or 10 days later.
3. From four to five weeks after the second application.

The date for the first application at Monticello, Fla., during the season of 1915 was found to be May 15, and in 1916 it was May 12. The time of spraying, however, will vary somewhat according to latitude and the character of the season. The first and second applications are the most important in the control of the pecan nut case-bearer, as most of the damage to the nuts is usually caused by the larvæ of the first generation. Since only a small portion of the nut crop is attacked by the second-brood larvæ, it is suggested that if growers desire to reduce spraying of their orchards to a minimum

³ Determined by W. R. Walton.

⁴ Determined by R. A. Cushman.

⁵ Determined by R. A. Cushman. The genus *Cremastus* now embraces the old genus *Zaleptopygus*.

⁶ In connection with life-history investigations, spraying experiments were conducted during 1915 and 1916, the results of which were reported in detail in Farmers' Bulletin 843 of the United States Department of Agriculture, pages 6 to 9. Further spraying experiments were begun in the spring of 1917, but could not be successfully carried out on account of the mildness of the infestation of the insect in the orchard selected for this work.

the last application be omitted, but that the first and second applications be made very thorough.

It is realized that the control recommendations given for this insect are not altogether satisfactory, but in the light of present knowledge they are the best that can be offered. Further detailed investigations are now being made to determine, if possible, a more effective method of controlling the pecan nut case-bearer, as well as other pecan insects of economic importance. Some time must necessarily elapse before reporting on these investigations, and in the meanwhile pecan growers are urged to use the control measures recommended.

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FUMIGATION AGAINST GRAIN WEEVILS WITH VARIOUS VOLATILE ORGANIC COMPOUNDS

By

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PURPOSE OF INVESTIGATION

Weevils destroy many million dollars' worth of wheat and other grains annually. Carbon disulphide is extensively used as a fumigant against these insects, but, although efficacious, it has serious disadvantages. It has an extremely disagreeable odor and in moderate concentrations its vapor is poisonous to man. Although carbon disulphide is volatile, millers occasionally complain that wheat which has been treated with it retains its odor, and it has been shown that the baking quality of flour from carbon disulphide fumigated wheat is sometimes injured (8).³

The really serious objection to the use of carbon disulphide as a fumigant, however, arises from the fact that it is readily inflammable and that its vapor when mixed with air is highly explosive. For this reason fire insurance companies refuse to carry the fire risk on elevators during the time carbon disulphide is being used to treat the grain contained in them. Even more important is the action taken by the General Managers' Association of Chicago, representing the leading railway systems of the United States, in adopting the following resolution:

That because of the highly inflammable character of solution of carbon disulphide and tetrachloride, its use for fumigating cars to be loaded with grain be prohibited, except that the Illinois Central may continue its use at New Orleans

¹ Deceased June 19, 1923.

² Credits due Maj. A. Gibson, formerly of the Chemical Warfare Service, for obtaining poisonous materials from the laboratories of Edgewood Arsenal; G. W. Kirby, of the Insecticide and Fungicide Laboratory, Bureau of Chemistry, for assistance in the chemical work; J. H. Cox, Harold Anderson, and the Milling and Baking Laboratory of the Grain Division, Bureau of Agricultural Economics, for assistance in carrying out the car-fumigation tests.

³ Italic numbers in parentheses refer to Literature Cited, p. 39.

and the Baltimore & Ohio at Locust Point, Md., when cars are isolated and protected, until some other satisfactory suitable substance can be provided, and further, that each carrier, member of this association, shall issue, without delay, necessary instructions prohibiting its use.

The following resolution was also adopted at the same time by this association:

That because of the presence of bran bug and weevil in grain and the great danger being done thereby, the chairman of this association communicate with the Bureau of Agriculture, Washington, D. C., advising of the action taken by this association and recommending that such investigations as may be necessary be made by the Government to produce a substance for this purpose which can be used with safety.

The investigation reported in this bulletin was undertaken because of the action taken by these railroad officials.

Carbon tetrachloride, hydrocyanic acid gas, sulphur dioxide, chloropicrin, naphthalene, phosgene, arsine, cyanogen chloride, and many other substances have been tested as fumigants for grain weevils by various investigators, who have reached the following conclusions: Carbon tetrachloride is ineffective under practical conditions; hydrocyanic acid gas fails to kill weevils very far below the surface of the grain; sulphur dioxide has low toxicity, injures ironwork, destroys the germinating power of wheat, makes a sticky dough (4), and retards fermentation, the bread obtained being heavy and unfit for consumption; carbon dioxide is effective only in tightly sealed containers and at relatively high concentrations; chloropicrin shows promise of being a practical fumigant, but is not yet commercially available; naphthalene is not very effective and has an objectionable odor; phosgene is poisonous to man, comparatively nonpoisonous to insects, and, because of its high vapor pressure, difficult to control; the toxicity of arsine to insects is comparatively low; the effect of cyanogen chloride as an insecticide is practically the same as that of hydrocyanic acid.

It is evident, therefore, that there is great need for a fumigant which will be effective against injurious insects in wheat and other cereals and also noninflammable and nonexplosive and neither dangerous nor highly disagreeable to those who handle it. The object of the investigation here reported was to discover such a fumigant, which could be used in place of carbon disulphide. In connection with this investigation, much information on the relation of the chemical constitution of compounds to their toxicological action on insects was acquired.

EXPERIMENTAL PROCEDURE

The rice weevil (*Sitophilus oryza* L.), the flour weevil (*Tribolium confusum* Fab.), and the granary weevil (*Sitophilus granarius* L.) were used in most of the tests, and the Indian meal moth (*Plodia interpunctella* Hbn.) was used in a great many. Adult insects of the weevils and the larvæ of the Indian meal moth were used.

The first series of experiments (Tables 1 and 2) were conducted in the apparatus described by Neifert (18). Four-liter glass jars, containing 10 to 20 live weevils of each species tested, were filled with a mixture of air of 40 per cent relative humidity and the vapor of the compound to be tested. After standing for 24 hours at room temperature (21° to 32° C.), the percentage of dead weevils was determined. (All specimens were examined after 24 hours, and also after 48 hours, to avoid reporting as dead those which might

have been only stupefied.) To obtain the desired humidity, air was bubbled through bottles of sulphuric acid of the proper density, the vapor pressure of water in sulphuric acid-water mixtures being known for mixtures of various densities. In the less volatile compounds, the quantity of the compound present in the jar in the form of vapor was determined by passing a known volume of air over a weighed quantity of the compound. The loss in weight (in grams) of the compound divided by the quantity of air (in liters) gives the quantity (in grams) of substance present in the form of vapor per liter of air.

The following factors were used in calculating the results reported:

Grams per liter $\times 62.43$ = pounds per 1,000 cubic feet.

Grams per liter $\times \frac{22.4 \times 100}{\text{gram-molecular weight}}$ = percentage concentration.

Percentage concentration $\times$ gram-molecular weight $\times 0.02787$ = pounds per 1,000 cubic feet.

1 cubic foot = 28.32 liters.

1 kilogram = 2.20462 pounds.

Assuming the vapor of a compound to be a perfect gas, the molecular weight (in grams) of this vaporized compound will occupy 22.4 liters under a pressure of 760 millimeters of mercury and at a temperature of 0° C. For example, the molecular weight of chloroform is approximately 119.4. Therefore, if 22.4 liters of space contains 119.4 grams of chloroform vapor (equivalent to 5.33 grams per liter), the percentage concentration is 100.

Since the tests were made at about the same temperature on compounds differing greatly in vapor pressure, it follows that the more volatile compounds were tested in high molar concentrations and the slightly volatile compounds were tested in low molar concentrations, which, however, were the maximum concentrations of the vapors possible at the temperature of the test.

EFFECT OF VOLATILE ORGANIC COMPOUNDS ON WEEVILS

The results of the fumigation of weevils in glass flasks at room temperature (21° to 32° C.) are shown in Table 1. Table 2 gives the formula, molecular weight, boiling point, and minimum lethal concentration for each compound tested.

TABLE 1.—Results of fumigation tests on weevils in glass flasks at room temperature (21° to 32° C.)

Test No.	Temperature	Fumigant	Concentration offumigant		Weevils killed after exposure for 24 hours			
			Molar per- cent- age	Pounds per 1,000 cu. ft.	<i>S. oryza</i>	<i>S. gran- arius</i>	<i>Tribol- ium</i>	<i>Plodia</i>
HYDROCARBONS:	° C.				<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
311.....	25.0	Amylene.....	40.31	78.76	100	100	100	-----
343.....	21.5	do.....	14.73	28.78	0	0	0	-----
347.....	22.5	do.....	21.26	41.54	0	0	0	-----
94.....	28.5	Kerosene.....	1.40	1.43	0	0	0	10
83.....	23.0	Cyclohexane.....	13.00	30.48	100	100	100	85
139.....	30.5	do.....	14.00	32.82	100	100	100	70
35.....	28.5	Benzene.....	13.00	23.29	100	100	100	100
130.....	28.5	do.....	.90	1.96	0	0	0	0
133.....	29.0	do.....	1.60	3.48	10	30	80	0
136.....	30.5	do.....	3.80	8.27	100	100	100	70
37.....	28.5	Toluene.....	3.00	7.70	75	50	100	80
23.....	30.0	o-Xylene.....	1.40	4.14	60	0	0	-----
14.....	24.0	Napthalene (25 per cent) and carbon tetrachlo- ride (75 per cent).	1.50	1.79	75	25	-----	25
39.....	28.5	Anthracene.....	.01	.05	0	0	0	0

¹ Molecular weight of kerosene assumed to be 128.

² Concentration of naphthalene only.

TABLE 1.—Results of fumigation tests on weevils in glass flasks at room temperature (21° to 32° C.)—Continued

Test No.	Temperature	Fumigant	Concentration of fumigant		Weevils killed after exposure for 24 hours			
			Molar per- cent- age	Pounds per 1,000 cu. ft.	<i>S. oryza</i>	<i>S. granarius</i>	Tribolium	Plodia
					<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
BROMIDES:								
50.....	31.0	Bromoform.....	0.94	6.62	100	80	90	100
365.....	23.0	Ethyl bromide.....	53.50	162.48	100	100	100	100
373.....	25.5	do.....	16.80	51.02	100	100	100	100
376.....	25.0	do.....	14.20	43.13	100	100	100	100
378.....	25.5	do.....	8.80	26.73	0	0	0	0
380.....	24.0	do.....	12.70	38.57	100	100	100	100
382.....	24.0	do.....	8.00	24.30	100	100	100	100
404.....	24.0	do.....	7.60	23.08	100	100	100	100
405.....	25.0	do.....	4.00	12.15	100	100	100	100
410.....	27.0	do.....	4.30	13.06	100	100	100	100
412.....	28.0	do.....	3.30	10.02	100	100	100	100
414.....	28.0	do.....	2.90	8.81	100	100	100	100
419.....	24.0	do.....	1.70	5.16	0	0	0	0
420.....	24.0	do.....	1.20	3.64	100	100	100	100
421.....	24.0	do.....	.70	2.13	0	0	0	0
366.....	23.0	Ethylene bromide.....	1.30	6.81	100	100	100	100
374.....	25.5	do.....	.50	2.62	100	100	100	100
377.....	25.0	do.....	.20	1.05	100	30	80	80
379.....	25.5	do.....	.30	1.57	0	0	80	80
381.....	24.0	do.....	.30	1.57	75	50	100	100
383.....	24.0	do.....	.20	1.05	100	0	80	80
278.....	26.0	<i>n</i> -Propyl bromide.....	12.79	43.84	100	100	100	100
280.....	26.0	do.....	13.84	47.44	100	100	100	100
308.....	25.0	do.....	5.50	18.85	100	100	100	100
313.....	25.0	do.....	7.26	24.89	100	100	100	100
326.....	24.5	do.....	5.54	18.99	100	100	100	100
331.....	24.0	do.....	4.00	13.71	100	50	100	100
353.....	24.0	do.....	4.01	13.75	0	0	0	0
367.....	24.0	do.....	4.90	16.80	100	100	100	100
369.....	24.0	do.....	4.10	14.05	100	100	100	100
385.....	24.0	do.....	2.20	7.54	0	0	0	0
483.....	26.0	Allyl bromide.....	15.30	51.59	100	100	100	100
486.....	26.0	do.....	8.00	26.97	100	100	100	100
489.....	25.0	do.....	3.90	13.15	100	100	100	100
275.....	26.0	<i>n</i> -Butyl bromide.....	5.27	20.12	100	100	100	100
277.....	26.0	do.....	5.30	20.24	100	25	100	100
307.....	25.0	do.....	2.64	10.08	100	100	100	100
312.....	25.0	do.....	2.56	9.78	100	100	100	100
325.....	24.5	do.....	1.63	6.22	80	25	100	100
330.....	24.0	do.....	1.09	4.16	0	25	15	10
54.....	32.0	Bromobenzene.....	.77	3.37	20	0	0	0
295.....	23.0	do.....	.56	2.45	0	0	0	0
297.....	23.5	do.....	.55	2.41	0	0	0	0
58.....	30.0	Benzyl bromide.....	.12	.57	0	0	0	20
CHLORIDES:								
518.....	25.0	Methylene chloride.....	39.50	93.51	100	100	100	100
520.....	25.0	do.....	8.10	19.18	0	0	100	100
524.....	25.0	do.....	16.80	39.77	100	100	100	100
525.....	25.0	do.....	14.20	33.62	100	100	100	100
541.....	26.0	do.....	4.40	10.42	100	100	100	100
580.....	28.0	do.....	3.40	8.05	100	0	0	0
581.....	28.0	do.....	2.20	5.21	100	100	100	100
582.....	28.0	do.....	1.20	2.84	100	0	0	0
583.....	28.0	do.....	1.10	2.60	100	100	100	100
19.....	31.0	Chloroform.....	20.00	66.55	100	100	100	100
69.....	28.5	do.....	2.30	7.65	0	0	0	0
79.....	30.0	do.....	15.00	49.91	100	100	100	100
104.....	28.5	do.....	3.20	10.65	95	45	100	50
106.....	29.0	do.....	7.00	23.29	100	100	100	80
109.....	29.0	do.....	13.90	46.25	100	100	100	100
11.....	30.0	Carbon tetrachloride.....	2.00	8.58	0	0	0	0
239.....	23.0	do.....	10.05	43.09	100	100	100	100
240.....	24.0	do.....	12.21	52.35	100	100	100	100
249.....	24.0	do.....	10.31	44.21	100	100	100	100
250.....	23.5	do.....	6.86	29.41	100	100	100	100
89.....	28.5	Ethylidene chloride.....	20.00	55.16	100	100	100	100
153.....	25.5	do.....	10.20	28.13	100	100	100	100
156.....	26.0	do.....	10.90	30.06	100	100	100	100
159.....	26.5	do.....	2.00	5.52	0	0	20	10
162.....	27.0	do.....	1.30	3.59	0	0	75	10
88.....	28.5	Trichloroethane.....	4.00	14.87	100	100	100	100
114.....	28.0	do.....	3.80	14.13	100	100	100	100
117.....	29.0	do.....	1.90	7.06	100	90	100	65
120.....	30.0	do.....	.90	3.35	95	0	0	65
123.....	30.0	do.....	.48	1.78	0	0	100	10

TABLE 1.—Results of fumigation tests on weevils in glass flasks at room temperature (21° to 32° C.)—Continued

Test No.	Temperature	Fumigant	Concentration of fumigant		Weevils killed after exposure for 24 hours			
			Molar per-centage	Pounds per 1,000 cu. ft.	<i>S. oryza</i>	<i>S. granarius</i>	Tribolium	Plodia
CHLORIDES—Con.			° C.		<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
126	30.0	Trichloroethane	0.22	0.82	0	0	70	0
497	24.0	do	2.80	10.41	100	100	100	100
499	26.0	do	1.60	5.95	100	100	100	100
501	26.0	do	.80	2.97	100	100	100	100
503	24.0	do	.40	1.49	0	0	0	0
505	24.0	do	.20	.74	100	100	100	100
512, 513	23.0	do	.40	1.49	0	0	0	0
516	24.5	do	.20	.74	0	0	0	0
526	25.0	do	.80	2.97	50	50	50	50
527	25.0	do	.80	2.97	100	100	75	75
528, 529	26.0	do	.50	1.86	50	50	50	50
530	25.0	do	1.10	4.09	100	100	100	100
531	25.5	do	1.10	4.09	100	100	100	100
66	28.5	s-Tetrachloroethane	1.00	4.68	60	0	0	50
78	29.5	do	1.10	5.15	100	100	100	100
96	30.0	do	1.10	5.15	100	60	100	90
98	30.0	do	.46	2.15	60	50	100	90
100	30.0	do	.23	1.08	70	50	100	60
87	28.5	Ethylene chloride	10.00	27.58	100	100	100	100
113	28.0	do	12.00	33.10	100	100	100	100
116	29.0	do	6.00	16.55	100	100	100	100
119	29.0	do	3.00	8.27	95	50	100	85
122	30.0	do	1.40	3.86	0	0	100	25
125	30.0	do	.73	2.01	90	20	100	20
84	31.0	Trichloroethylene	10.00	36.62	100	100	100	100
95	30.0	do	10.00	36.62	100	100	100	100
97	30.0	do	5.00	18.31	10	0	0	10
99	30.0	do	2.10	7.69	100	100	100	100
102	30.0	do	1.05	3.85	0	0	0	70
146	30.0	do	5.00	18.31	65	60	100	20
150	30.0	do	2.50	9.16	50	15	80	0
574	26.0	Tetrachloroethylene	2.60	12.02	100	100	100	100
575	26.0	do	1.30	6.01	50	0	100	100
576	26.0	do	.60	2.77	0	0	0	0
577	26.0	do	.30	1.39	0	0	0	0
55	32.0	Acetylene dichloride	9.02	24.37	100	100	100	80
141	29.0	do	28.00	75.65	100	100	100	100
145	30.0	do	16.80	45.39	100	100	100	100
149	30.0	do	6.90	18.64	60	0	90	0
536	26.0	Propylene dichloride	6.10	19.21	100	100	100	100
537	26.0	do	2.80	8.82	100	100	100	100
538	26.0	do	1.20	3.78	100	100	100	100
556	27.0	do	1.10	3.46	100	100	70	70
557	27.0	do	1.00	3.15	100	100	80	80
558	27.0	do	.70	2.20	100	100	60	60
559	27.0	do	.70	2.20	100	100	0	0
92	28.5	Isopropyl chloride	18.00	39.40	0	0	65	50
1	26.0	Monochlorobenzene	1.00	3.14	100	100	100	100
2	26.0	do	.25	.78	100	100	100	100
3	26.0	do	.10	.31	100	0	100	0
4	26.0	do	.50	1.57	100	0	80	100
8	30.0	do	2.00	6.27	100	100	100	100
9	30.0	do	1.00	3.14	100	50	100	100
15	29.5	do	2.00	6.27	75	32	100	20
16	30.5	do	2.00	6.27	90	50	100	20
65	28.5	do	7.70	24.15	100	100	100	95
138	30.5	o-Dichlorobenzene	.60	2.46	0	0	0	0
5	26.0	p-Dichlorobenzene	1.00	4.10	100	50	100	50
10	30.0	do	1.00	4.10	85	75	100	100
7	30.0	o and p-Dichlorobenzene	2.00	8.19	100	100	100	100
13	30.0	do	1.00	4.10	100	50	100	100
FLUORIDES:								
465	24.0	Fluorobenzene	14.30	38.29	100	100	100	100
467	24.0	do	7.20	19.28	100	100	100	100
469	24.0	do	3.40	9.10	100	100	100	100
471	24.5	do	1.90	5.00	100	100	100	100
474	23.0	do	2.20	5.89	0	0	100	100
476	23.0	do	1.90	5.00	100	100	25	25
60	30.5	Diffuorodiphenyl	.002	.01	0	0	0	10
IODIDES:								
302	25.0	n-Butyl iodide	1.61	8.26	100	100	100	100
303	25.0	do	1.54	7.90	100	100	100	100
316	24.5	do	.79	4.05	100	100	100	100
337	21.5	do	.43	2.21	0	0	0	0
340	24.0	do	.36	1.85	0	0	0	0

TABLE 1.—Results of fumigation tests on weevils in glass flasks at room temperature (21° to 32° C.)—Continued

Test No.	Temperature	Fumigant	Concentration of fumigant		Weevils killed after exposure for 24 hours			
			Molar per cent-age	Pounds per 1,000 cu. ft.	<i>S. oryza</i>	<i>S. gran-arius</i>	<i>Tribolium</i>	<i>Plodia</i>
ALCOHOLS AND PHENOLS:								
	° C.				<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
34	28.5	Methyl alcohol	16.00	14.28	100	100	100	100
129	28.5	do	1.00	.89	0	0	0	0
132	29.0	do	2.00	1.79	0	0	0	0
135	30.0	do	4.50	4.02	30	15	5	10
64	30.5	Ethyl alcohol	8.00	10.27	0	0	0	15
21	30.5	n-Propyl alcohol	3.50	5.86	100	100	-----	100
71	32.0	do	1.70	2.85	96	50	100	100
111	29.0	do	1.70	2.85	100	100	100	100
137	30.5	do	1.50	2.51	20	0	15	85
81	30.0	n-Butyl alcohol	1.70	3.51	100	60	100	100
20	31.0	Isoamyl alcohol	.80	1.96	100	100	-----	80
142	29.0	do	.77	1.89	80	60	100	100
144	30.0	do	.33	.81	0	0	0	0
148	30.0	do	.20	.49	0	0	0	0
68	28.5	Geraniol	.10	.43	10	0	0	0
59	30.5	Menthol	.08	.35	0	0	0	80
46	30.0	Thymol	.09	.38	0	0	0	0
ALDEHYDES:								
67	28.5	Chloral hydrate	.20	.92	20	0	0	0
289	25.0	n-Butyraldehyde	11.15	22.40	100	100	100	-----
291	25.0	do	9.46	19.00	100	100	100	-----
321	26.0	do	5.53	11.11	100	100	100	-----
335	21.5	do	3.27	6.57	0	0	100	-----
338	24.0	do	2.59	5.20	0	0	90	-----
464	24.0	Crotonaldehyde	4.00	7.81	100	-----	100	-----
466	24.0	do	2.00	3.91	100	-----	100	-----
468	24.0	do	1.30	2.54	100	-----	100	-----
470	24.5	do	.50	.98	100	-----	0	-----
473	23.0	do	.60	1.17	100	-----	100	-----
475	23.0	do	.50	.98	100	-----	75	-----
18	30.5	Furfural	.80	2.14	100	100	-----	20
52	31.0	Benzaldehyde	.27	.80	100	100	55	75
KETONES:								
33	28.5	Acetone	15.00	24.27	100	100	100	100
128	28.5	do	2.00	3.24	5	10	10	0
131	28.5	do	4.10	6.63	95	100	15	25
134	30.0	do	8.20	13.27	100	100	100	100
219	24.0	Chloroacetone	1.53	3.94	100	100	100	-----
220	23.0	do	.70	1.80	100	100	100	-----
232	24.0	do	.42	1.08	100	100	100	-----
243	26.0	do	.22	.57	0	0	0	-----
268	25.0	do	.42	1.08	100	100	100	-----
270	25.0	do	.26	.67	100	100	100	-----
80	23.0	Ethyl methyl ketone	15.00	30.13	100	100	100	100
140	29.0	do	13.30	26.72	100	100	100	100
143	29.0	do	7.20	14.46	100	100	100	100
147	30.0	do	3.40	6.83	100	70	100	80
151	30.0	do	1.80	3.62	100	80	100	0
304	25.0	Mesityl oxide	1.53	4.18	100	100	100	-----
309	25.0	do	1.42	3.88	100	100	100	-----
341	21.0	do	.39	1.07	0	0	0	-----
345	22.5	do	.55	1.50	100	50	0	-----
352	23.0	do	.60	1.64	100	100	0	-----
53	31.0	Acetophenone	.16	.54	100	45	0	50
6	30.0	Chloroacetophenone (5 per cent) in carbon tetrachloride (95 per cent).	$\left\{ \begin{array}{l} \text{\$.10} \\ \text{\$.01} \end{array} \right\}$	$\left\{ \begin{array}{l} .43 \\ .04 \end{array} \right\}$	100	-----	-----	100
12	30.0		$\left\{ \begin{array}{l} \text{\$.01} \\ \text{\$.17} \end{array} \right\}$	$\left\{ \begin{array}{l} .04 \\ .73 \end{array} \right\}$	0	0	-----	0
63	30.5				0	0	0	5
ESTERS:								
217	26.0	Methyl formate	56.00	93.71	100	100	100	-----
222	23.0	do	20.37	34.09	100	100	100	-----
234	24.5	do	11.62	19.44	100	100	100	-----
241	25.5	do	6.35	10.63	100	100	100	-----
259	26.0	do	4.54	7.60	100	100	100	-----
260	26.0	do	3.64	6.09	100	100	100	-----
271	24.5	do	3.64	6.09	0	0	0	-----
272	24.5	do	4.10	6.86	100	100	100	-----
273	24.5	do	2.65	4.43	100	100	100	-----
474A, 475A	24.5	do	3.50	5.86	100	-----	100	-----
476A	24.5	do	2.00	3.35	100	-----	100	-----
506	24.0	do	1.30	2.18	100	-----	100	-----
507	24.0	do	.90	1.51	100	-----	100	-----
284	24.5	Ethyl formate	20.37	42.05	100	100	100	-----
286	24.5	do	22.41	46.26	100	100	100	-----
319	26.0	do	15.04	31.04	100	100	100	-----
328	24.0	do	10.00	20.64	100	100	100	-----

³ Concentration of chloroacetophenone only.

TABLE 1.—Results of fumigation tests on weevils in glass flasks at room temperature (21° to 32° C.)—Continued

Test No.	Temperature	Fumigant	Concentration of fumigant		Weevils killed after exposure for 24 hours			
			Molar per-cent-age	Pounds per 1,000 cu. ft.	<i>S. oryza</i>	<i>S. gran-arius</i>	Tribolium	Plodia
ESTERS—Con.								
333	24.0	Ethyl formate	6.41	13.23	<i>P. ct.</i> 100	<i>P. ct.</i> 100	<i>P. ct.</i> 100	<i>P. ct.</i> 100
357	24.0	do	4.89	10.09	100	100	100	100
359	23.0	do	3.71	7.66	100	100	100	100
389	25.0	do	1.80	3.72	100	100	100	100
391	25.0	do	.60	1.24	100	100	100	100
406	25.0	do	1.30	2.68	100		100	
407	25.0	do	1.10	2.27	100		80	
408	25.0	do	.90	1.86	100		100	
411A	23.0	do	1.10	2.27	100		100	
412A, 422	23.0	do	.80	1.65	100		100	
423	23.0	do	.40	.83	0		0	
424	23.0	do	.60	1.24	100		0	
426, 428	25.0	do	.50	1.03	0		0	
484	26.0	Isopropyl formate	15.50	38.05	100		100	
487	26.0	do	8.20	20.13	100		100	
490	25.0	do	3.90	9.57	100		100	
492	25.5	do	2.00	4.91	100		100	
494	25.5	do	1.00	2.45	50		0	
514	24.0	do	1.20	2.95	100		100	
515	25.0	do	.90	2.21	100		100	
532	26.5	do	1.10	2.70	100		100	
533	26.5	do	.90	2.21	100		100	
542	26.0	do	.80	1.96	100		80	
543	26.0	do	.50	1.23	100		0	
166	27.0	Methyl cyano formate	.20	.47	16	0	100	100
167	27.5	do	.32	.76	88	90	100	100
169	28.0	do	.08	.19	24	55	15	95
175	27.0	do	.90	2.13	100	100	100	100
176	27.5	do	.68	1.61	100	100	100	100
177	27.5	do	.40	.95	95	90	100	100
178	27.5	do	.30	.71	50	50	100	100
38	27.5	<i>n</i> -Propyl acetate	3.50	9.96	100	100	100	100
73	32.0	do	2.50	7.11	100	100	100	100
155	25.5	do	3.70	10.53	95	90	100	100
158	26.0	do	1.90	5.41	90	50	100	100
161	27.0	do	1.00	2.85	0	0	0	0
44	30.0	<i>n</i> -Butyl acetate	.76	2.46	70	20	95	100
282	26.0	Isobutyl acetate	1.68	5.44	0	0	0	0
283	26.0	do	1.56	5.05	0	0	0	0
45	30.0	Isoamyl acetate	1.50	5.44	100	100	100	100
75	31.0	do	.90	3.26	100	100	100	100
101	30.0	do	.54	1.96	20	50	75	85
103	30.0	do	.24	.87	0	0	0	0
294	23.0	Ethyl- <i>n</i> -valerate	.77	2.79	0	0	0	0
296	23.5	do	.66	2.39	0	0	0	0
ETHERS:								
292	25.0	Acetal	4.86	16.00	100	100	100	100
293	25.0	do	4.34	14.29	100	100	100	100
322	26.5	do	2.27	7.47	50	20	100	100
344	21.5	do	1.72	5.66	0	0	80	100
348	22.5	do	1.70	5.60	100	100	100	100
351	23.0	do	1.64	5.40	50	20	100	100
521	27.0	do	4.40	14.49	100		100	
523	27.0	do	1.10	3.62	100		0	
274	26.0	Chloromethyl ether	2.34	5.25		100	100	100
275	26.0	do	2.22	4.98		100	100	100
218	26.0	<i>s</i> -Dichloromethyl ether	4.87	15.60	100	100	100	100
221	23.0	do	3.89	12.46	100	100	100	100
233	24.0	do	1.13	3.62	100	100	100	100
244	26.0	do	.62	1.99	50	50	90	100
267	25.0	do	1.21	3.88	100	100	100	100
269	25.0	do	.70	2.24	0	0	0	0
CHLOROHYDRINS:								
517	25.0	Ethylene chlorohydrin	1.40	3.14	0		0	0
519	25.0	do	.30	.67	0		0	0
288	24.5	Epichlorohydrin	1.95	5.03	100	100	100	100
290	25.0	do	1.93	4.98	100	100	100	100
320	26.0	do	1.19	3.07	100	100	100	100
329	24.0	do	.73	1.88	100	100	100	100
334	24.0	do	.59	1.52	100	100	100	100
358	23.0	do	.42	1.08	100	100	100	100
360	23.0	do	.41	1.06	100	100	100	100
363	23.0	do	.25	.64	100	100	100	100
388	25.0	do	.20	.52	100	100	100	100
390	25.0	do	.10	.26	100	100	100	100
397	25.0	do	.09	.23	100		50	
398	25.0	do	.09	.23	100		0	

TABLE 1.—Results of fumigation tests on weevils in glass flasks at room temperature (21° to 32° C.)—Continued

Test No.	Temperature	Fumigant	Concentration of fumigant		Weevils killed after exposure for 24 hours			
			Molar per-cent-age	Pounds per 1,000 cu. ft.	<i>S. oryza</i>	<i>S. gran-arius</i>	<i>Tribolium</i>	<i>Plodia</i>
SULPHUR COM-POUNDS:								
115	28.0	Carbon disulphide	46.00	97.59	100	100	100	100
118	29.0	do	24.70	52.40	100	100	100	100
121	30.0	do	12.30	26.10	100	100	100	100
124	30.0	do	6.40	13.58	100	100	100	100
127	30.0	do	3.00	6.36	100	100	100	100
164	27.0	do	3.30	7.00	100	100	100	100
165	27.0	do	2.50	5.30	100	100	100	100
168	27.5	do	1.10	2.33	100	100	100	100
170	26.0	do	1.00	2.12	100	35	70	100
171	26.0	do	.50	1.06	0	0	0	0
172	27.0	do	.47	1.00	0	0	0	0
173	27.0	do	.50	1.06	0	0	0	0
174	27.0	do	.11	.23	0	0	0	0
93	28.5	Ethyl mercaptan	19.00	32.89	100	100	100	100
29	31.5	<i>n</i> -Butyl mercaptan	3.00	7.54	100	100	100	100
72	32.0	do	2.00	5.03	100	100	100	100
152	25.5	do	5.40	13.57	100	100	100	100
154	25.5	do	2.30	5.78	100	100	100	100
157	26.0	do	.90	2.26	100	20	80	0
160	26.5	do	.30	.75	0	0	0	10
163	27.0	do	.10	.25	0	0	0	0
216	26.0	Methyl sulphide	53.80	93.14	100	100	100	-----
223	23.0	do	20.98	36.32	100	100	100	-----
235	25.0	do	9.45	16.36	50	0	100	-----
242	25.0	do	10.44	18.07	100	100	100	-----
256	23.5	do	9.75	16.88	90	0	100	-----
257	24.0	do	9.49	16.43	100	100	100	-----
258	23.5	do	5.00	8.66	0	0	50	-----
265	25.0	do	12.87	22.28	60	0	100	-----
266	25.0	do	11.54	19.98	100	100	100	-----
215	26.0	Ethyl sulphide	4.91	12.34	100	100	100	-----
224	24.0	do	2.92	7.34	100	100	100	-----
236	25.0	do	1.50	3.77	20	10	90	-----
245	25.5	do	1.72	4.32	95	80	80	-----
261	24.5	do	3.65	9.17	100	100	100	-----
262	25.0	do	3.72	9.35	100	100	100	-----
264	25.0	do	2.34	5.88	50	0	100	-----
213	26.0	Methyl thiocyanate	1.84	3.75	100	100	100	-----
226	24.0	do	.78	1.59	100	100	100	-----
237	25.0	do	.36	.73	100	100	100	-----
246	26.0	do	.20	.41	100	100	100	-----
253	26.5	do	.20	.41	100	100	100	-----
254	26.5	do	.14	.29	100	100	100	-----
255	26.0	do	.09	.18	0	0	0	-----
263	26.0	do	.10	.20	100	20	30	-----
214	26.0	Ethyl thiocyanate	1.04	2.53	100	100	100	-----
225	24.0	do	.46	1.12	100	100	50	-----
229	23.0	do	.46	1.12	5	0	100	-----
231	24.0	do	.19	.46	100	100	50	-----
238	23.0	do	.71	1.72	0	0	0	-----
402	24.0	do	.80	1.94	100	-----	100	-----
51	31.0	Allyl isothiocyanate	1.14	3.15	100	100	100	100
77	29.5	do	.70	1.93	100	100	100	100
107	29.0	do	.34	.94	100	100	100	100
110	29.0	do	.62	1.71	100	100	100	100
30	28.5	Cyanogen sulphide	.10	.23	0	0	0	0
31	28.5	Mercaptol	.16	1.16	0	0	0	0
28	30.5	Perchloromethyl mer- captol	1.00	5.18	60	100	25	0
90	28.5	<i>p</i> -Toluenesulphochloride	.15	.80	0	0	0	100
NITRILES AND ISO-NITRILES:								
305	25.0	Acetonitrile	11.60	13.27	100	100	100	-----
310	25.0	do	12.13	13.87	100	100	100	-----
342	21.0	do	3.47	3.97	0	0	0	-----
346	22.5	do	4.97	5.68	100	100	100	-----
371	26.5	do	3.90	4.46	50	0	0	-----
372	26.5	do	5.70	6.52	100	100	100	-----
430*	25.0	Propionitrile	1.30	1.99	0	-----	0	-----
414A	24.0	<i>n</i> -Valeronitrile	1.10	2.55	100	-----	100	-----
416	24.0	do	.60	1.39	50	-----	30	-----
418	24.0	do	.30	.69	0	-----	0	-----
26	30.0	Phenylisocnitrile	.12	.34	0	0	0	0
425	25.0	Phenylacetoneitrile	.10	.33	100	-----	90	-----
427	25.0	do	.03	.10	0	-----	0	-----
429	25.0	do	.02	.07	0	-----	0	-----
437	25.0	do	.07	.23	0	-----	0	-----
438	25.0	do	.03	.10	0	-----	0	-----

TABLE 1.—Results of fumigation tests on weevils in glass flasks at room temperature (21° to 32° C.)—Continued

Test No.	Temperature	Fumigant	Concentration of fumigant		Weevils killed after exposure for 24 hours			
			Molar per-cent-age	Pounds per 1,000 cu. ft.	<i>S. oryza</i>	<i>S. gran-arius</i>	Tribolium	Plodia
	° C.				<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
NITRITES:								
413A	24.0	<i>n</i> -Butyl nitrite	9.10	26.15	100	100	100	100
415A	24.0	do.	4.30	12.36	90	100	90	100
417	24.0	do.	2.20	6.32	100	100	100	100
434	25.0	do.	1.60	4.60	100	100	100	100
435	25.0	do.	1.10	3.16	100	100	100	100
436	25.0	do.	1.00	2.87	100	100	100	100
442	24.0	do.	.60	1.72	100	100	100	100
443	24.0	do.	.60	1.72	100	100	66	100
444	24.0	do.	.30	.86	50	100	8	100
279	26.0	Isoamyl nitrite	4.70	15.34	100	100	100	100
281	26.0	do.	4.84	15.80	100	100	100	100
318	24.5	do.	2.36	7.70	100	100	100	100
327	24.0	do.	1.46	4.77	100	100	100	100
332	24.0	do.	1.02	3.33	100	50	100	100
354	24.0	do.	1.13	3.69	0	0	0	0
368	24.0	do.	1.40	4.57	100	100	100	100
370	26.0	do.	1.10	3.59	100	75	100	100
384	24.0	do.	.80	2.61	100	100	100	100
399	25.0	do.	1.20	3.92	100	100	100	100
400	25.0	do.	.80	2.61	100	100	100	100
411	23.0	do.	.70	2.28	100	100	50	100
413	24.0	do.	.60	1.96	100	100	100	100
415	24.0	do.	.80	2.61	100	100	100	100
NITRO COMPOUNDS:								
298	23.5	Nitromethane	4.35	7.40	100	100	100	100
300	25.0	do.	4.59	7.81	100	100	100	100
323	26.5	do.	3.57	6.07	100	100	100	100
336	21.5	do.	1.27	2.16	0	0	0	0
339	24.0	do.	1.03	1.75	0	0	0	0
32	28.5	Nitrobenzene	.10	.34	0	0	0	0
49	31.0	do.	.12	.41	0	0	0	0
S2	30.0	<i>p</i> -Chloronitrobenzene	.12	.53	0	0	0	0
S5	31.0	<i>m</i> -Dinitrobenzene	.28	1.31	0	0	0	0
86	28.5	α -Nitronaphthalene	.10	.48	0	0	0	0
AMINES:								
496	24.0	Diethylamine	20.60	41.98	100	100	100	100
498	24.0	do.	11.80	24.04	100	100	100	100
500	26.0	do.	5.80	11.82	100	100	100	100
502	25.0	do.	2.60	5.30	100	100	100	100
504	23.5	do.	1.10	2.24	100	100	100	100
509	24.0	do.	.90	1.83	100	100	100	100
511	23.0	do.	.50	1.02	100	100	100	100
534	26.0	do.	.80	1.63	50	50	50	50
535	26.0	do.	.50	1.02	50	50	100	100
482	26.0	<i>n</i> -Butylamine	10.20	20.78	100	100	100	100
485	26.0	do.	5.30	10.80	100	100	100	100
488	27.0	do.	2.80	5.71	100	100	100	100
491	25.5	do.	1.30	2.65	100	100	100	100
493	25.5	do.	.60	1.22	100	100	100	100
508	24.0	do.	.30	.61	50	0	0	0
510	24.0	do.	.20	.41	0	0	0	0
43	29.5	Aniline	1.89	4.90	0	0	0	0
47	29.0	Methylaniline	.13	.39	0	0	0	0
56	30.0	Dimethylaniline	.15	.51	0	0	0	0
57	30.0	Ethylbenzylaniline	.03	.18	0	0	0	0
62	30.5	Acetphenylenediamine	.07	.29	0	0	0	0
91	28.5	α -Naphthylamine	.016	.06	0	0	0	0
MISCELLANEOUS NITROGENOUS COMPOUNDS:								
48	30.0	Pyridine	1.69	3.72	100	100	100	100
76	31.0	do.	.84	1.85	100	100	100	100
105	29.0	do.	.17	.37	0	0	0	0
108	29.0	do.	.39	.86	10	5	10	20
112	29.0	do.	.83	1.83	100	100	75	65
61	30.5	Hexamethylenetetramine	.002	.008	0	0	0	0
INORGANIC COMPOUNDS:								
477A	23.5	Carbon dioxide	100.00	122.64	100	100	100	100
478A	24.5	do.	100.00	122.64	65	100	40	100
479	24.5	do.	50.00	61.32	100	100	25	100
480	24.5	do.	33.00	40.47	0	0	0	0
481	24.5	do.	50.00	61.32	100	100	100	100
495	25.5	do.	50.00	61.32	100	100	0	100
522	27.0	do.	50.00	61.32	100	100	0	100
41	29.0	Thionyl chloride	5.00	16.58	100	100	100	100
74	32.0	do.	4.50	14.92	100	100	100	100

TABLE 2.—*Formulæ, molecular weights, boiling points, and lethal concentrations (from results in Table 1) of fumigants*

Fumigant	Formula	Molecular weight ¹	Boiling point ²	Lethal concentration ³ (molar percentage)			
				<i>S. oryza</i>	<i>S. granarius</i>	Tribolium	Plodia
° C.							
HYDROCARBONS:							
Amylene	C ₆ H ₁₀	70. 105	22-37	40.3	40.3	40.3	
Kerosene	Mixture		150-280				
Cyclohexane	C ₆ H ₁₂	84. 126	80.8	413.0	413.0	413.0	13.0
Benzene	C ₆ H ₆	78. 078	79-81	3.8	3.8	3.8	
Toluene	C ₆ H ₅ CH ₃	92. 099	109-110			3.0	
<i>o</i> -Xylene	C ₆ H ₄ (CH ₃) ₂	106. 120	143.5-144.5				
Naphthalene	C ₁₀ H ₈	128. 114	218				
Anthracene	C ₁₄ H ₁₀	178. 150	351				
BROMIDES:							
Bromoform	CHBr ₃	252. 773	142-151	.9			
Ethyl bromide	C ₂ H ₅ Br	108. 970	38-40	2.9	48.0	2.9	
Ethylene bromide	C ₂ H ₄ Br ₂	187. 882	127-132	.5	.5	.5	
<i>n</i> -Propyl bromide	C ₃ H ₇ Br	122. 991	70-71	4.1	4.1	4.1	
Allyl bromide	C ₃ H ₅ Br	120. 975	69-71	4.3	9.9	4.3	9.9
<i>n</i> -Butyl bromide	C ₄ H ₉ Br	137. 012	100-101		2.6	1.6	
Bromobenzene	C ₆ H ₅ Br	156. 990	154-155	2.6			
Benzyl bromide	C ₆ H ₅ CH ₂ Br	171. 011	198-199				
CHLORIDES:							
Methylene chloride	CH ₂ Cl ₂	84. 941	40.5-42	4.4		4.4	
Chloroform	CHCl ₃	119. 393	58-61.5	7.0	7.0	3.2	13.9
Carbon tetrachloride	CCl ₄	153. 845	76-77	6.9	6.9	6.9	
Acetylene dichloride	C ₂ H ₂ Cl ₂	96. 946	55	9.0	9.0	9.0	16.8
Ethylene chloride	C ₂ H ₄ Cl ₂	98. 962	83-84	6.0	6.0	4.7	6.0
Ethylidene chloride	C ₂ H ₃ Cl ₂	98. 962	59.5-61.5	10.2	10.2	10.2	10.2
Trichloroethane	C ₂ H ₃ Cl ₃	133. 414	74.5	.8	3.8	1.1	3.8
Trichloroethylene	C ₂ HCl ₃	131. 398	85.5-87	10.0	10.0	10.0	10.0
Tetrachloroethane	C ₂ H ₂ Cl ₄	167. 866	144-146	1.1	1.1	1.1	1.1
Tetrachloroethylene	C ₂ Cl ₄	165. 850	119-121	2.6	2.6	1.3	
Propylene dichloride	C ₃ H ₄ Cl ₂	112. 983	95-96	4.7		1.2	
Isopropyl chloride	(CH ₃) ₂ CHCl	78. 531	34-36				
Monochlorobenzene	C ₆ H ₅ Cl	112. 530	128-132	2.0	2.0		2.0
<i>o</i> -Dichlorobenzene	C ₆ H ₄ Cl ₂	146. 982	178-181				
<i>p</i> -Dichlorobenzene	C ₆ H ₄ Cl ₂	146. 982	172-174				
<i>o</i> and <i>p</i> -Dichlorobenzene	C ₆ H ₄ Cl ₂	146. 982		1.0	2.0		1.0
FLUORIDES:							
Fluorobenzene	C ₆ H ₅ F	96. 070	84.9	4.9		2.2	
Diffuorodiphenyl	C ₆ H ₅ F-C ₆ H ₅ F	190. 124	254-255				
IODIDES:							
<i>n</i> -Butyl iodide	C ₄ H ₉ I	184. 012	129-131	.8	.8	.8	
ALCOHOLS AND PHENOLS:							
Methyl alcohol	CH ₃ OH	32. 037	65	16.0	16.0	16.0	16.0
Ethyl alcohol	C ₂ H ₅ OH	46. 058	78				
<i>n</i> -Propyl alcohol	C ₃ H ₇ OH	60. 079	96-98	1.7	3.5	1.7	1.7
<i>n</i> -Butyl alcohol	C ₄ H ₉ OH	74. 100	114-118	4.7		4.7	4.7
Isoamyl alcohol	C ₅ H ₁₁ OH	88. 121	130-132	.8	.8	.8	.8
Geraniol	C ₁₅ H ₁₅ CH ₂ OH	154. 194	230				
Thymol	(CH ₃) ₂ C=CHC ₆ H ₃ (CH ₃)OH	150. 162	223-232				
Menthol	C ₁₀ H ₁₉ OH	156. 210	210				
ALDEHYDES:							
Chloral hydrate	CCl ₃ CH(OH) ₂	165. 414	97.5				
<i>n</i> -Butyraldehyde	C ₄ H ₇ CHO	72. 084	75-77.5	5.5	5.5	3.3	
Crotonaldehyde	CH ₃ CH=CHCHO	70. 068	104-105	4.5		.6	
Furfural	C ₄ H ₃ OCHO	96. 057	161	4.8	4.8		
Benzaldehyde	C ₆ H ₅ CHO	106. 083	179	4.3	4.3		
KETONES:							
Acetone	CH ₃ COCH ₃	58. 063	55-56	8.2	4.1	8.2	8.2
Chloroacetone	CH ₂ ClCOCH ₃	92. 515	117-119	.26	.26	.26	
Ethyl methyl ketone	C ₂ H ₅ COCH ₃	72. 084	79-80	4.8	7.2	4.8	7.2
Mesityl oxide	(CH ₃) ₂ C=CHCOCH ₃	98. 110	130-131	.55	.6	1.4	
Acetophenone	C ₆ H ₅ COCH ₃	120. 104	202	4.6			
Chloroacetophenone	C ₆ H ₅ COCH ₂ Cl	154. 556	247	.10			.10
ESTERS:							
Methyl formate	HCOOCH ₃	60. 042	31.5-32.5	4.9	4.2	6.5	4.9
Ethyl formate	HCOOC ₂ H ₅	74. 063	53.5-55	.6	4.6	.8	
Isopropyl formate	HCOOCH(CH ₃) ₂	88. 084	63-64	4.5		.9	
Methyl cyano formate	CNCOOCH ₃	85. 047	100-101	.7	.7	.2	.2
<i>n</i> -Propyl acetate	CH ₃ COOC ₃ H ₇	102. 105	99-102	2.5	2.5	1.9	1.9
<i>n</i> -Butyl acetate	CH ₃ COOC ₄ H ₉	116. 126	124-126				4.76
Isobutyl acetate	CH ₃ COOC ₄ H ₉	116. 126	115-117				
Isoamyl acetate	CH ₃ COOC ₅ H ₁₁	130. 147	138-140	.9	.9	.9	.9
Ethyl <i>n</i> -valerate	C ₆ H ₅ COOC ₆ H ₁₃	130. 147	144-145.5				

¹ Based on international atomic weight values for 1922.² The boiling points given are those of the substances as tested, not those of these compounds of the highest degree of purity.³ The lethal concentration here reported represents the minimum percentage concentration which consistently caused 100 per cent mortality after exposure for 24 hours. Since in some cases the concentrations tested varied decidedly and because of some variation in the experimental results, the results here given do not necessarily represent the exact minimum lethal concentration.⁴ Minimum concentration tested.

TABLE 2.—*Formulae, molecular weights, boiling points, and lethal concentrations (from results in Table 1) of fumigants—Continued*

Fumigant	Formula	Molecular weight	Boiling point	Lethal concentration (molar percentage)			
				<i>S. oryza</i>	<i>S. granarius</i>	<i>Tribolium</i>	<i>Plodia</i>
° C.							
ETHERS:							
Acetal.....	CH ₃ CH(OC ₂ H ₅) ₂	118.142	102-104.....	4.3	4.3	1.7	-----
Chloromethyl ether.....	CH ₂ ClOCH ₃	80.510	55-60.....	⁴ 2.2	⁴ 2.2	⁴ 2.2	-----
<i>s</i> -Dichloromethyl ether.....	CH ₂ ClOCH ₂ Cl.....	114.962	100-108.....	1.1	1.1	1.1	-----
CHLOROHYDRINS:							
Ethylenechlorohydrin.....	CH ₂ ClCH ₂ OH.....	80.510	126-127.....	-----	-----	-----	-----
Epichlorohydrin.....	C ₂ H ₅ ClO.....	92.515	115-117.....	⁴ 0.9	⁴ 1.0	⁴ 1.0	-----
SULPHUR COMPOUNDS:							
Carbon disulphide.....	CS ₂	76.125	46.....	1.0	1.1	1.1	1.0
Ethyl mercaptan.....	C ₂ H ₅ SH.....	62.118	34.5-35.5.....	⁴ 19.0	⁴ 19.0	⁴ 19.0	⁴ 19.0
<i>n</i> -Butyl mercaptan.....	C ₄ H ₉ SH.....	90.160	96-98.....	9	2.0	2.0	2.0
Methyl sulphide.....	(CH ₃) ₂ S.....	62.118	38-39.....	10.4	10.4	9.5	-----
Ethyl sulphide.....	(C ₂ H ₅) ₂ S.....	90.160	92-93.....	2.9	2.9	2.3	-----
Methyl thiocyanate.....	CH ₃ SCN.....	73.102	130-131.....	1	¹⁴ 14	¹⁴ 14	-----
Ethyl thiocyanate.....	C ₂ H ₅ SCN.....	87.123	146-147.....	8	1.0	8	-----
Allyl isothiocyanate.....	C ₃ H ₅ NCS.....	99.128	143-151.....	⁴ 3	⁴ 3	⁴ 3	⁴ 3
Cyanogen sulphide.....	(CN) ₂ S.....	84.086	(Sublimes 30-40°)	-----	-----	-----	-----
Mercaptol.....	(CH ₂) ₂ C(C ₆ H ₅ S) ₂	260.323	-----	-----	-----	-----	-----
Perchloromethyl mercaptol.....	CCl ₃ SCl.....	185.905	146.5-148.....	⁴ 1.0	-----	-----	-----
<i>p</i> -Toluenesulphochloride.....	C ₇ H ₇ SO ₂ Cl.....	190.611	145-146 (15 mm.)	-----	-----	-----	⁴ 1.5
NITRILES AND ISONITRILES:							
Acetonitrile.....	CH ₃ CN.....	41.042	76-82.....	5.0	5.0	5.0	-----
Propionitrile.....	C ₃ H ₇ CN.....	55.063	96-97.....	-----	-----	-----	-----
<i>n</i> -Valeronitrile.....	C ₅ H ₉ CN.....	83.105	139-141.....	1.1	-----	1.1	-----
Phenylisocyanide.....	C ₆ H ₅ NC.....	103.083	165-166.....	-----	-----	-----	-----
Phenylacetonitrile.....	C ₆ H ₅ CH ₂ CN.....	117.104	231.7.....	1	-----	-----	-----
NITRITES:							
<i>n</i> -Butyl nitrite.....	C ₄ H ₉ NO ₂	103.100	77-79.....	6	-----	1.0	-----
Isoamyl nitrite.....	C ₅ H ₁₁ NO ₂	117.121	96-99.....	⁴ 6	1.4	8	-----
NITRO COMPOUNDS:							
Nitromethane.....	CH ₃ NO ₂	61.037	98-101.....	3.6	3.6	3.6	-----
Nitrobenzene.....	C ₆ H ₅ NO ₂	123.078	209.4.....	-----	-----	-----	-----
<i>p</i> -Chloronitrobenzene.....	ClC ₆ H ₄ NO ₂	157.530	242.....	-----	-----	-----	-----
<i>m</i> -Dinitrobenzene.....	C ₆ H ₄ (NO ₂) ₂	168.078	297.....	-----	-----	-----	-----
α -Nitronaphthalene.....	C ₁₀ H ₇ NO ₂	173.114	304.....	-----	-----	-----	-----
AMINES:							
Diethylamine.....	(C ₂ H ₅) ₂ NH.....	73.116	55-56.....	9	-----	4.5	-----
<i>n</i> -Butylamine.....	C ₄ H ₉ NH ₂	73.116	76-78.....	6	-----	6	-----
Aniline.....	C ₆ H ₅ NH ₂	93.094	182.....	-----	-----	-----	-----
Methylaniline.....	C ₆ H ₅ NHCH ₃	107.115	193.5.....	-----	-----	-----	-----
Dimethylaniline.....	C ₆ H ₅ N(CH ₃) ₂	121.136	192.....	-----	-----	-----	-----
Ethylbenzylaniline.....	C ₆ H ₅ N(C ₂ H ₅)CH ₂ C ₆ H ₅	211.219	255-256.....	-----	-----	-----	-----
Acetphenylenediamine.....	NH ₂ C ₆ H ₄ NHCOCH ₃	150.136	-----	-----	-----	-----	-----
α -Naphthylamine.....	C ₁₀ H ₇ NH ₂	143.130	300.....	-----	-----	-----	-----
MISCELLANEOUS NITROGENOUS COMPOUNDS:							
Pyridine.....	C ₅ H ₅ N.....	79.073	116-118.....	.83	.83	.83	.83
Hexamethylenetetramine.....	C ₆ H ₁₂ N ₄	140.158	-----	-----	-----	-----	-----
INORGANIC COMPOUNDS:							
Carbon dioxide.....	CO ₂	44.005	-78.5.....	50.0	-----	100.0	-----
Thionyl chloride.....	SOCl ₂	118.980	78.....	⁴ 4.5	⁴ 4.5	⁴ 4.5	⁴ 4.5

⁴ Minimum concentration tested.

HYDROCARBONS

Against grain weevils, a 100 per cent kill was obtained with amyrene at a concentration of 40.31 per cent, with cyclohexane at a concentration of 13 per cent, and with benzene at a concentration of 3.8 per cent. Against all of the insects except *Tribolium*, kerosene, toluene, *o*-xylene, naphthalene, and anthracene were not more than 75 per cent effective.

Trillat and Legendre (26) found that benzene and toluene vapors at a concentration of 10 grams per cubic meter were insufficient to kill mosquitoes after exposure for an hour at 20° to 28° C.

Holt (9) tried the effect of benzene, toluene, xylene, naphthalene, anthracene, "benzoline," heptane, petrol, petroleum ether, and paraffin oil (boiling point, 150° to 289° C.), in concentrations of 1 drachm

to 1,250 cubic centimeters, on roaches (*Periplaneta orientalis* L.) confined in a glass-stoppered 1,250-cubic centimeter bottle. Benzene and toluene showed the same toxicity. In general, the higher the boiling point the longer the time necessary to kill. "Benzoline" (boiling point, 60° C.), which killed in 17 minutes, was the most toxic.

McClintock, Hamilton, and Lowe (13) compared the toxicity of the vapors of naphthalene, kerosene, Australene, Oregon fir turpentine, oil turpentine, Michigan wood turpentine, and oil of *Pinus palustris* on bedbugs, cockroaches, house flies, clothes moths, and mosquitoes in an 800-liter hood. Naphthalene was the most toxic.

Jewson and Tattersfield (10) found that naphthalene vapor had no apparent effect on mites (*Aleurobius farinæ* De G.), even after exposure for 16 hours.

Lloyd (12) found pure naphthalene, free from tarry acids, to be a poor fumigant against adult greenhouse white flies (*Asterochiton vaporariorum* Westw.). At a temperature of 69° to 72° F., 0.5 gram of pure naphthalene killed only 3 per cent of the adult white flies confined in a half-gallon glass-stoppered jar during exposure for an hour.

Lefroy (11) found that xylene, turpentine, cymene, and pseudocumene killed 100 per cent, and that eucalyptus oil killed some mealworms dipped in the liquid.

Russell (22) found toluene more effective than carbon disulphide in the partial sterilization of sick soil in which tomatoes were growing.

Titschack (25) found the vapor of benzene to be very much less effective than carbon disulphide against the eggs, larvæ, and moths of the clothes moth (*Tineola biselliella* Hum.). Xylene also showed a low toxicity, but naphthalene was effective.

Richardson and Smith (21) found the toxicity toward the black aphid (*Aphis rumicis* L.) to increase from benzene through toluene to xylene, but in all cases the tolerance of the host plant, nasturtium, was much less than the minimum toxic concentration. Cyclohexane was twice as toxic as benzene.

Tattersfield and Roberts (24) found that anthracene and phenanthrene were nontoxic to wireworms; that mesitylene, *p*-cymene, and naphthalene had marginal toxicity; and that *n*-pentane, *n*-hexane, *n*-heptane, benzene, toluene, and *m*- and *p*-xylene had low toxicity. Of the hydrocarbons examined only pseudocumene had moderate toxicity. Moore (15) found that the toxicity of petroleum ether, benzene, toluene, xylene, gasoline, camphene, naphthalene, and kerosene toward flies increased with diminishing volatility.

The low toxicity and ready inflammability of all the hydrocarbons tested make this class of organic compounds unpromising in the search for a practical fumigant.

BROMIDES

The most effective bromide tested during the investigation reported in this bulletin was ethylene bromide, which killed 100 per cent of the weevils at a concentration of only 0.5 per cent. The order of toxicity of the other bromides follows: Bromoform, *n*-butyl, ethyl, allyl, *n*-propyl, and benzyl bromide, and bromobenzene.

Bromoform and monobromobenzene were found by Tattersfield and Roberts (24) to be moderately toxic to wireworms. Moore (14) tested the action on flies of bromobenzene, *p*-dibromobenzene, *o*- and *p*-bromotoluene, and bromoxylene. The disubstitution products were more toxic than the monosubstitution products, and the bromine

compounds were more toxic than the corresponding chlorine compounds. From tests on potato-beetle eggs with bromoform, trimethylene bromide, *o*-bromotoluene, and bromoxylene, Moore and Graham (17) concluded that the toxicity of organic compounds to insect eggs increased with decreasing volatility. Moore (15) also tested the action of bromoform, brometone (tribromo tertiary butyl alcohol), and ethylene bromide on flies.

Bertrand and Rosenblatt (2) found benzyl bromide to be more toxic than carbon disulphide, but less toxic than monochloroacetone to the larvæ of (*Bombyx*) *Malacosoma neustria* L.

Holt (9) found that it took nine minutes for the vapor of bromoform (0.8 gram per liter) to kill cockroaches (*Periplaneta orientalis* L.), as compared with eight minutes for carbon disulphide at the same concentration.

Organic bromides have the disadvantage of being costly. While the bromides are in general more effective than the corresponding chlorides, they can not be expected to give an economical fumigant, because liquid bromine is usually quoted at a price four to five times that of chlorine; furthermore, 35.5 units by weight of chlorine are the chemical equivalent of about 80 units by weight of bromine.

Ethylene bromide and ethyl bromide (Tables 3, 4, 5, 6, 7, 8) are the only bromides which seem worth a further trial.

CHLORIDES

Trichloroethane, *s*-tetrachloroethane, propylene dichloride, and a mixture of *o*- and *p*-dichlorobenzene gave 100 per cent mortality in concentrations of 2 per cent or less. Other chlorides showed the following order of toxicity: Monochlorobenzene, *p*-dichlorobenzene, tetrachloroethylene, methylene chloride, ethylene chloride, carbon tetrachloride, chloroform, acetylene dichloride, trichloroethylene, ethylidene chloride, and isopropyl chloride.

Tattersfield and Roberts (24) experimented with wireworms. Dichloroethylene, trichloroethylene, carbon tetrachloride, chloroform, and tetrachloroethane, in the aliphatic series, and monochlorobenzene and *o*-chlorotoluene, in the aromatic series, had a low toxicity; 1, 2, 4-trichlorobenzene, monochloroxylene, *p*-dichlorobenzene, and benztetrachloride had a marginal toxicity; *o*-dichlorobenzene and benzal chloride had a moderate toxicity; and benzyl chloride had a high toxicity.

Parker and Long (19), using several chlorides against the larvæ of *Trogoderma khapra* Arrow, at a concentration of 10 ounces per 1,000 cubic feet and an exposure of 1,000 minutes, obtained a mortality of 11 per cent with carbon tetrachloride, 27.7 per cent with trichloroethylene, 73.3 per cent with tetrachloroethane, and 77.7 per cent with pentachloroethane.

Holt (9), Trillat and Legendre (26), Bertrand and Rosenblatt (2), Lefroy (11), McClintock, Hamilton, and Lowe (13), Titschack (25), and many other investigators report that chloroform has a low toxicity against various insects.

Altson (1), using the vacuum method commonly employed with hydrocyanic acid gas, found tetrachloroethane useless for the fumigation of beetles in wood. He recommends both *o*- and *p*-dichlorobenzene as a deterrent to timber beetles.

Lloyd (12) reports that tetrachloroethane gives good results against the white fly in greenhouse fumigation, but is without

effect on the eggs. About half a pint per 1,000 cubic feet should be used, and the fumigation should be continued for not less than 18 hours. Lloyd states that:

It has been used for a wide variety of plants, including tomatoes, and no damage has resulted except in one case when the foliage of three young sycamores (*Acer pseudo-planatus*)⁴ growing in pots turned brown the day after the fumigation and was subsequently shed.

Speyer (23) also found tetrachloroethane effective against adult white flies, but its effect on the red spider was only temporary. The tetrachloroethane, when used at the rate of 10 ounces per 1,000 cubic feet, severely injured several varieties of chrysanthemum.

Richardson and Smith (21) found that 34 and 31 grams per 100 cubic centimeters of chloroform and carbon tetrachloride, respectively, were necessary to kill aphids, and that the tolerance of the nasturtium plant for these two compounds varied from 5 to 8. Chlorobenzene and commercial trichlorobenzene were less toxic to aphids than carbon disulphide, and their toxic concentrations exceeded the tolerance of the plant.

Moore (14, 15) used chlorobenzene, *p*-dichlorobenzene, chloroform, carbon tetrachloride, and chloreton (trichloro tertiary butyl alcohol) in various tests on flies.

FLUORIDES

Fluorobenzene at a concentration of 1.9 per cent showed 100 per cent mortality against *Sitophilus oryza*, but difluorodiphenyl exhibited almost no toxicity, owing probably to its slight volatility at the temperature of the test.

Organic fluorine compounds have not been tested by many investigators, probably because they are rare and expensive.

IODIDES

The only iodide tested, normal butyl iodide, killed all the weevils at a concentration of 0.8 per cent.

Moore (14) found iodobenzene to be more toxic to house flies than the corresponding bromine and chlorine compounds.

Tattersfield and Roberts (24) found iodoform to be nontoxic to wireworms, while iodobenzene was moderately toxic.

According to Holt (9), cockroaches dusted with iodoform did not succumb until a period of 9 hours had elapsed.

ALCOHOLS AND PHENOLS

Methyl alcohol was more toxic than ethyl alcohol, but with this exception the toxicity increased with increasing molecular weight through isoamyl alcohol. Thymol, menthol, and geraniol are so slightly volatile at ordinary temperature as to be practically nontoxic.

Richardson and Smith (21) found methyl, ethyl, *n*-propyl, *n*-butyl, capryl, isoamyl, benzyl, and furfuryl alcohols to be ineffective against aphids. Even pure methyl and ethyl alcohols killed less than 95 per cent of the insects.

Moore (15) found the toxicity of methyl, ethyl, and amyl alcohols, menthol, and thymol on house flies to increase with decreasing volatility.

Trillat and Legendre (26) showed that methyl, ethyl, propyl, and amyl alcohols had only a feeble toxicity to mosquitoes.

⁴Sycamore maple.

Titschack (25) showed that ethyl alcohol was ineffective against the eggs and larvæ of clothes moths.

McClintock, Hamilton, and Lowe (13) found the effectiveness of methyl and ethyl alcohols to be low against bedbugs, cockroaches, house flies, clothes moths, and mosquitoes. Menthol was about half as toxic to bedbugs as carbon disulphide.

Holt (9) found methyl alcohol to be more toxic to cockroaches than ethyl or amyl alcohol. All required at least 45 minutes to produce death, however.

Lefroy (11) reported that 70 per cent ethyl alcohol failed to kill any mealworms dipped in it.

Burmeister in 1836 (3, p. 39) recorded instances of beetles which after being immersed in spirits of wine for 12 hours recovered all their functions when removed from it.

Apparently alcohols of the fatty acid series have low toxicity to insects and are not suited for fumigants.

ALDEHYDES

Crotonaldehyde was much more toxic than *n*-butyraldehyde. Furfural and benzaldehyde showed marked toxicities at concentrations of less than 1 per cent. The chlorine-substituted aldehyde, chloral hydrate, had low toxicity.

Richardson and Smith (21) tested paraldehyde, aldehyde ammonia, chloral hydrate, furfural, and benzaldehyde against aphids. Even benzaldehyde, the most effective, was not a practical aphicide, as a 5 per cent solution was required to kill.

None of the many experimenters with formaldehyde, an effective fungicide, has discovered any practical value for it as a fumigant against insects. Phelps and Stevenson (20) found a 0.5 per cent solution to be effective as a stomach poison to flies, possessing a coefficient of 2.32 as compared with a coefficient of 1 for 0.001 normal arsenite solution. Four and 8 per cent formaldehyde solutions were less effective than the 0.5 per cent solution; a 1 per cent solution had a coefficient of 2.36. The addition of molasses and brown sugar diminished the effectiveness of the formaldehyde solutions. Dry powdered paraformaldehyde showed a coefficient of only 0.14, while a saturated solution had a coefficient of 1.90.

Moore (15) found that the toxicity of acetaldehyde, chloral hydrate, and furfural to house flies in general increased as their volatilities decreased.

According to Davis (5), acetaldehyde is ineffective against white grubs in soil. Trillat and Legendre (26) report that it has only a feeble toxicity for mosquitoes.

Lefroy (11) found a solution of chloral hydrate in water to have no effect on mealworms. Holt (9) reports that roaches dusted with powdered chloral hydrate survived for 4 hours.

McClintock, Hamilton, and Lowe (13) found benzaldehyde to be more effective than carbon disulphide against bedbugs, cockroaches, and house flies, equally effective against clothes moths, and less than half as toxic to mosquitoes.

KETONES

Ethyl methyl ketone was more effective than acetone (dimethyl ketone). The introduction of chlorine into a ketone, as in chloroacetone, enormously increased its toxicity.

Richardson and Smith (21) found that even 100 per cent acetone and ethyl methyl ketone killed less than 95 per cent of aphids, and acetal was effective only in concentrations over 50 per cent.

Moore (15) found the toxicity of acetone, bromomethyl phenyl ketone, and menthone to house flies to increase with diminishing volatility.

Holt (9) found that it took acetone vapor 32 minutes to kill cockroaches, as against 8 minutes for carbon disulphide.

Lefroy (11) found that acetone killed no mealworms dipped in it.

According to McClintock, Hamilton, and Lowe (13), acetone has very little effect against bedbugs, cockroaches, house flies, clothes moths, and mosquitoes.

Titschack (25) found acetone less effective than carbon disulphide against the eggs and larvæ of clothes moths.

Guérin and Lormand (7) found that bromoacetone had no apparent effect on plants at a concentration of 1 to 2,000 exposed for an hour.

Bertrand and Rosenblatt (2) found monochloroacetone to be very much more active against the larvæ of (*Bombyx*) *Malacosoma neustria* L. than ether, chloroform, carbon tetrachloride, or carbon disulphide, but less active than hydrocyanic acid or chloropierin.

ESTERS

The esters showed a higher toxicity to weevils than any other class of organic compounds tested. Methyl, ethyl, isopropyl, and methyl cyano formates and isoamyl acetate are more toxic, molecule for molecule, than carbon disulphide. Propyl acetate is less toxic than carbon disulphide; *n*-butyl acetate, isobutyl acetate, and ethyl-*n*-valerate are so slightly volatile at the temperatures used that they do not give 100 per cent mortality in the concentrations obtained.

Richardson and Smith (21) tested the action on aphids of amyl acetate, methyl salicylate, and benzyl acetate. Benzyl acetate, at a concentration of about 1 per cent, was the most effective.

Moore (15) tried the effect on house flies of methyl salicylate, ethyl malonate, ethyl acetoacetate, amyl acetate, amyl valerate, and propyl acetate.

Lefroy (11) found that amyl acetate killed all mealworms dipped in it, while methyl salicylate and ethyl acetate killed some.

Moore (16) tried the effect of a wide variety of substances on the clothes louse. He concluded that liquids less volatile or more volatile than creosote are not as successful, and that, while not quite as good, crude phenol and methyl salicylate are the best substitutes.

ETHERS

s-Dichloromethyl ether had an efficiency comparable to that of carbon disulphide; chloromethyl ether was about half as effective. Acetal was effective at a concentration of slightly over 4 per cent.

Ethyl ether was the most volatile and least toxic of all materials used by Moore (15) against house flies.

Ethyl ether has been tested by a number of other experimenters, but in all cases it showed only a low toxicity against insects.

CHLOROHYDRINS

Epichlorohydrin, the most toxic substance tested in this investigation, killed 100 per cent of *S. oryza* at a concentration of only 0.09 per cent. Ethylene chlorohydrin at the maximum concentration tested, 1.4 per cent, was ineffective.

Apparently chlorohydrins have not been tested by other experimenters with insecticides.

SULPHUR COMPOUNDS

Methyl and ethyl thiocyanates and allyl isothiocyanate were more effective than carbon disulphide; methyl and ethyl sulphides and ethyl mercaptan were less effective than carbon disulphide. Butyl mercaptan was as effective as carbon disulphide against *S. oryza*, but only half as effective against the other species of weevils.

Mercaptol is so slightly volatile as to be ineffective. Cyanogen sulphide killed no weevils at a concentration of 0.1 per cent; perchloromethylmercaptol and *p*-toluenesulphochloride gave variable kills.

Richardson and Smith (21) found that a concentration exceeding 5 per cent of carbon disulphide was necessary to kill aphids, whereas a solution containing less than 2 per cent injured the nasturtium plant.

According to Moore (15), molecule for molecule, allyl isothiocyanate is more toxic against house flies than chloropicrin, and carbon disulphide and ethyl mercaptan are more toxic than their relative volatilities would indicate.

Tattersfield and Roberts (24) found allyl isothiocyanate to be the most toxic to wireworms of all compounds tested by them. The toxicity of carbon disulphide was equal to that of benzene.

Speyer (23) found ethyl mercaptan to have no effect on red spiders. It also failed to kill adult white flies.

NITRILES AND ISONITRILES

n-Valeronitrile had a toxicity as great as that of carbon disulphide; acetonitrile was about one-fifth as toxic as carbon disulphide. Propionitrile and phenylisonitrile were ineffective. Phenylacetoneitrile was the most toxic of this class of compounds, killing all *S. oryza* at a concentration of 0.10 per cent.

Moore (14) found that the toxicity of benzonitrile to house flies compared with that of iodobenzene and xylene.

NITRITES

n-Butyl nitrite and isoamyl nitrite were about equally toxic.

Moore (15) found that amyl nitrite had about the same toxicity to flies as gasoline.

Tattersfield and Roberts (24) found that the toxicity of amyl nitrate to wireworms was low and that the toxicity of amyl nitrite was moderate.

Speyer (23) found that the grubs of a chironomid fly (*Orthocladus*) came to the surface of the soil of cucumber pot plants and were killed in a short time when amyl nitrite and amyl nitrate were used. He also found that methyl nitrite had a more permanent effect on red spiders than amyl nitrate and tetrachlorethane, but that it was necessary to use concentrations which hurt the plants. The adults of the white fly were killed by all these vapors.

NITRO COMPOUNDS

Nitromethane was the only nitro compound which killed all of the insects; a concentration of 3.6 per cent was necessary. Nitrobenzene, *p*-chloronitrobenzene, *m*-dinitrobenzene, and α -nitronaphthalene at saturation concentrations killed none of the weevils.

Moore (15) found nitrobenzene even more toxic than nicotine to house flies.

Several nitro compounds have been tested against wireworms by Tattersfield and Roberts (24). *m*-Nitroaniline, *o*-nitroaniline, *p*-nitrophenol, nitronaphthalene, dinitrobenzene, and nitrobenzaldehyde were nontoxic; *o*- and *p*-nitrochlorobenzene, *o*- and *p*-nitrotoluene, *p*-nitroaniline, and nitroxylenes (mixed derivatives) had marginal toxicity; nitromethane had low toxicity; nitrobenzene had moderate toxicity; and *o*-nitrophenol and nitrochloroform (chloropicrin) had high toxicity.

AMINES

Diethylamine and *n*-butylamine were more toxic to weevils than carbon disulphide. None of the other amines tested (aniline, methylaniline, dimethylaniline, ethylbenzylaniline, acetphenylene-diamine, and α -naphthylamine), however, showed any toxicity.

Richardson and Smith (21) tested the action of the following compounds on aphids: Trimethylamine hydrochloride, tetramethylammonium chloride, *p*-phenylenediamine, phthalimidine, methylamine hydrochloride, diethylamine, triethylamine, triethylamine hydrochloride, tetraethylammonium chloride, tetrapropylammonium hydroxide, isobutylamine, diamylamine, triacetoneamine, hexamethylenetetramine, formamide, dicyanodiamide, choline hydrochloride, betaine hydrochloride, nitroguanidine, succinimide, aniline, benzylamine, benzidine hydrochloride, *m*-phenylenediamine hydrochloride, camphylamine, and tetrahydrobetanaphthylamine hydrochloride. None of these approached nicotine in toxicity. Tetramethylammonium chloride, the most effective, required a concentration of 0.35 per cent, compared with an effective concentration for nicotine of only 0.007 per cent.

Tattersfield and Roberts (24), in tests on wireworms, found that *o*- and *m*-nitroaniline, *m*-phenylenediamine, phenylhydrazine, naphthylamine, and diphenylamine were nontoxic; that *p*-nitroaniline and *p*-chloroaniline had marginal toxicity; that trimethylamine, ethylamine, dimethylamine, monomethylamine, aniline, and *o*-chloroaniline had moderate toxicity; and that *o*- and *p*-toluidine, xylydine, dimethylaniline, and monomethylaniline had high toxicity.

Foreman and Graham-Smith (6, p. 113) found aniline (saturated aqueous solution) and aniline hydrochloride to be toxic to flies when taken by the mouth. The hydrochloride of *o*-toluidine had a similar effect, but *p*-toluidine hydrochloride was nontoxic. Flies taking monomethylaniline hydrochloride appeared to be dead in 10 minutes, but recovered in 2 hours. Hydroxylamine hydrochloride in 2 per cent solution had little effect, or none, and a 1 per cent solution of *m*-phenylenediamine had no effect.

Jewson and Tattersfield (10) tested the action on mites (*Aleurobius farinæ*) of aniline, monomethylaniline, and dimethylaniline. Most of the large mites remained alive, but moved sluggishly.

MISCELLANEOUS NITROGENOUS COMPOUNDS

Pyridine at a concentration of 0.8 per cent killed all the weevils, but hexamethylenetetramine showed no killing power.

Richardson and Smith (21) sprayed aphids with the following pyridine and quinoline derivatives: Nicotinic acid nitrate, 4-dimethylaminoantipyrine, *n*-ethyl piperidine sulphate, *n*-ethyl piperidine, crude chloropiperidine, piperidine sulphate, pyridinium ethyl hydroxide, pyridine, pyridinium ethyl iodide, piperidine, methylene dipiperidine, γ γ dipyridyl, α -picoline, pyrrole, quinoline, tetrahydro-

quinoline, quinaldine, and piperazine. The minimum toxic concentration of pyridine was 25 grams per 100 cubic centimeters of solution. None of these compounds was more than one-hundredth as effective as nicotine.

McClintock, Hamilton, and Lowe (13) found little difference in the toxicity of pyridine, pyridine bases, and quinoline for bedbugs, cockroaches, house flies, clothes moths, and mosquitoes.

Jewson and Tattersfield (10) found pyridine effective against mites.

Lefroy (11) found that quinoline and pyridine killed some of the mealworms dipped in the liquids, but that a 1 per cent aqueous solution of nicotine killed none.

Tattersfield and Roberts (24) found that pyridine was moderately toxic against wireworms.

Moore (15) found pyridine somewhat more toxic than its position in the table of organic compounds arranged according to volatility would indicate. Its toxicity was about the same as that of furfural.

INORGANIC COMPOUNDS

None of the inorganic compounds tested proved suitable as a fumigant. Thionyl chloride killed all weevils at a concentration of 4.5 per cent; concentrations of carbon dioxide ranging from 50 to 100 per cent were required to effect a complete kill.

RELATION BETWEEN VOLATILITY AND TOXICITY OF FUMIGANTS

The compounds causing 100 per cent mortality to *S. oryza* (selected on account of its high resistance to fumigants) exposed to them for 24 hours, together with their boiling points, are listed in Table 3.

TABLE 3.—*Toxicity of fumigants to Sitophilus oryza* (arranged in order of decreasing effect)

Fumigant	Minimum concentration causing 100 per cent mortality in 24 hours	Boiling point ¹	Minimum quantity causing 100 per cent mortality in 24 hours	Cost per pound ²	Cost per 1,000 cubic feet
	<i>Per cent</i>	<i>° C.</i>	<i>Lbs. per 1,000 cu. ft.</i>	<i>Dollars</i>	<i>Dollars</i>
Epichlorohydrin.....	0.09	116.6	0.23	27.22	6.26
Phenylacetoneitrile.....	.10	231.7	.33	18.14	5.99
Chloroacetophenone.....	.10	247.0	.43	9.07	3.90
Methyl thiocyanate.....	.10	133.0	.20	27.22	5.44
Acetophenone.....	.16	202.0	.54	5.90	3.18
Chloroacetone.....	.26	119.0	.67	27.22	18.24
Benzaldehyde.....	.27	178.3	.80	1.13	.90
Allyl isothiocyanate.....	.34	150.7	.94	4.08	3.84
Crotonaldehyde.....	.50	104.0	.98		
Ethylene bromide.....	.50	129.0	2.62	.91	2.38
Isopropyl formate.....	.50	70.0	1.23	2.27	2.79
Mesityl oxide.....	.55	130.0	1.50	13.61	20.42
Isoamyl nitrite.....	.60	99.0	1.96	9.07	17.78
Ethyl formate.....	.60	54.4	1.24	.40	.50
n-Butyl nitrite.....	.60	75.0	1.72	3.63	6.24
n-Butylamine.....	.60	76.0	1.22	36.29	44.27
Methyl cyano formate.....	.68	100.0	1.61		
Propylene dichloride.....	.70	96.8	2.20	1.27	2.79
Furfural.....	.80	161.0	2.14	.25	.54
Trichloroethane.....	.80	74.1	2.97	2.27	6.74
Isoamyl alcohol.....	.80	131.0	1.96	1.81	3.55
n-Butyl iodide.....	.80	129.9	4.10	9.07	37.19
Ethyl thiocyanate.....	.80	146.0	1.94	22.68	44.00
Pyridine.....	.83	116.0	1.83	.36	.66

¹ Boiling points taken from Beilstein.

² Most of the prices are taken from List No. 10 of the Eastman Kodak Co., Rochester, N. Y., issued September, 1923; some are from wholesale quotations by the Oil, Paint, and Drug Reporter, March 3, 1924; and some are quotations from the Miner Laboratories, Chicago, Ill.

³ Minimum concentrations tested.

TABLE 3.—*Toxicity of fumigants to Sitophilus oryza (arranged in order of decreasing effect)*—Continued

Fumigant	Minimum concentration causing 100 per cent mortality in 24 hours	Boiling point	Minimum quantity causing 100 per cent mortality in 24 hours	Cost per pound	Cost per 1,000 cubic feet
	Per cent	° C.	Lbs. per 1,000 cu. ft.	Dollars	Dollars
Methyl formate.....	³ .90	32.3	1.51	1.59	2.40
Isoamyl acetate.....	.90	139.0	3.26	.91	2.97
Diethylamine.....	.90	55.0	1.83	16.33	29.83
<i>n</i> -Butyl mercaptan.....	.90	97.0	2.26	36.29	82.02
Bromoform.....	³ .94	150.5	6.62	2.04	13.50
<i>o</i> - and <i>p</i> -Dichlorobenzene.....	1.00	175.0	4.10	.15	.615
Carbon disulphide.....	1.00	46.0	2.12	.06	.127
<i>s</i> -Tetrachloroethane.....	1.10	147.0	5.15	1.13	5.82
<i>n</i> -Valeronitrile.....	1.10	141.0	2.55	27.22	69.41
<i>s</i> -Dichloromethyl ether.....	1.13	105.0	3.62	27.22	98.54
<i>n</i> -Propyl alcohol.....	1.70	97.4	2.85	1.36	3.88
<i>n</i> -Butyl alcohol.....	³ 1.70	117.0	3.51	.76	2.67
Ethyl methyl ketone.....	³ 1.80	79.6	3.62	.30	1.09
Fluorobenzene.....	³ 1.90	84.9	5.09		
Chlorobenzene.....	2.00	132.0	6.27	.09	.56
Chloromethyl ether.....	³ 2.20	59.5	4.94	13.61	67.23
<i>n</i> -Propyl acetate.....	2.50	101.6	7.11	2.27	16.14
<i>n</i> -Butyl bromide.....	2.60	101.0	9.93	4.54	45.08
Tetrachloroethylene.....	2.60	121.0	12.02	1.13	13.58
Ethyl sulphide.....	2.90	92.0	7.29	2.27	16.54
Ethyl bromide.....	2.90	38.4	8.81	.40	3.52
Nitromethane.....	3.60	101.0	6.12	9.07	55.51
Benzene.....	3.80	80.2	8.27	4.04	33
Allyl bromide.....	³ 3.90	70.0	13.15	15.88	208.82
<i>n</i> -Propyl bromide.....	4.10	70.8	14.05	13.61	191.22
Acetal.....	4.30	102.2	14.15	13.14	256.68
Methylene chloride.....	4.40	47.6	10.42	6.80	70.86
Thionyl chloride.....	³ 4.50	78.0	14.92	9.07	135.32
Acetonitrile.....	5.00	81.6	5.71	13.14	103.58
<i>n</i> -Butyraldehyde.....	5.50	77.0	11.05	13.61	150.39
Ethylene chloride.....	6.00	83.5	16.55	.68	11.25
Carbon tetrachloride.....	6.90	76.7	29.58	.082	2.44
Chloroform.....	7.00	61.2	23.29	.32	7.45
Acetone.....	8.20	56.5	13.27	.20	2.65
Acetylene dichloride.....	9.00	55.0	24.31		
Trichloroethylene.....	10.00	88.0	36.62	.36	13.18
Ethylidene chloride.....	10.20	59.2	28.13	22.68	637.99
Methyl sulphide.....	10.40	38.0	18.00	45.36	816.48
Cyclohexane.....	³ 13.00	80.8	30.48	22.68	691.29
Methyl alcohol.....	16.00	64.7	14.28	⁶ .15	2.14
Ethyl mercaptan.....	³ 19.00	37.0	32.89	9.07	298.31
Amylene.....	40.30	22-37	78.76	9.07	714.35
Carbon dioxide.....	50.00	-78.5	61.32	.07	4.29

³ Minimum concentrations tested.⁴ Chemically pure, in drums, sold for 30 cents a gallon.⁵ Purified, in drums, sold for \$1 a gallon.

While the volatility of organic compounds at ordinary temperatures is not proportional to their boiling points, very few data on the vapor pressure of these compounds at ordinary temperatures are available. For that reason the boiling points were used in this investigation. The compounds are arranged in the order of decreasing toxicity. Moore (15) states:

In general, the toxicity of a volatile organic compound is correlated closely with its volatility. A decreasing volatility is accompanied by an increased toxicity. The boiling point of the chemical is a general index of its volatility. Compounds with boiling points of 225° to 250° C. are usually so slightly volatile that they do not produce death except after very long exposures.

If this theory is true, the boiling points of the compounds should show a decrease, indicating increasing volatility, but no well-defined relation between the toxicity and the boiling point is shown in Table 3. This is not in agreement with Moore's theory.

TABLE 4.—Results of fumigation tests on weevils in grain in 19-liter glass bottles

Test No.	Fumigant		Average mortality	Weevils killed after exposure for 24 hours							
	Material	Concentration		Material	Concentration	Bottom of bottle		Middle of bottle		Top of bottle	
						<i>S. oryza</i>	<i>S. granarius</i>	<i>S. oryza</i>	<i>S. granarius</i>	<i>S. oryza</i>	<i>S. granarius</i>
	<i>Lbs. per 1,000 cu. ft.</i>	<i>Lbs. per 1,000 cu. ft.</i>	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
273-2	Methyl thiocyanate	0.35	Carbon tetrachloride	100	100	100	100	100	100	100	100
	do	.35		58	50	0	60	90	50	100	
	do	.47		59	30	0	100	100	25	100	
	do	.67		53	25	100	100	75	0	100	
273-1	Chloroacetone	1.00	do	100	100	100	100	100	100	100	100
	do	1.00	do	65	100	25	100	100	100	100	100
	do	1.25	do	75	25	75	100	100	100	50	100
	do	1.50	do	34	0	60	100	100	25	20	
375A	Turpentine	3.75	do	100	100	100	100	100	100	100	100
	do	5.00	do	100	100	100	100	100	100	100	100
	Ethylene bromide	3.10	do	100	100	100	100	100	100	100	100
	do	5.20	do	100	100	100	100	100	100	100	100
432	do	3.10	do	71	25	100	100	75	100	25	100
	do	6.20	do	100	100	100	100	100	100	100	100
	do	4.70	do	96	100	100	100	100	100	100	100
	do	2.90	do	100	100	100	100	100	100	100	100
451, 9	<i>n</i> -Butyl nitrite	2.90	do	67	100	100	100	0	100	100	100
	do	3.40	do	96	75	100	100	0	100	100	100
	do	4.90	do	100	100	100	100	100	100	100	100
	do	4.90	do	92	100	100	100	75	100	75	100
454	Crotonaldehyde	2.90	do	100	100	100	100	100	100	100	100
	Trichloroethane	5.58	do	21	0	0	0	0	75	0	50
	do	11.10	do	87	100	20	100	100	100	100	100
	Methyl formate	1.70	do	65	100	100	100	50	100	25	100
321	do	6.0	Ethyl bromide	100	100	90	100	100	100	100	100
	do	3.0	Carbon tetrachloride	50	0	100	100	50	100	100	100
	do	10.0	do	90	100	100	100	100	100	100	100
	do	1.03	do	42	0	50	0	100	0	100	100
460	do	2.06	do	100	100	100	100	100	100	100	100
	do	2.06	do	83	50	50	100	100	100	100	100
	do	2.50	do	100	100	100	100	100	100	100	100
	do	3.10	do	100	100	100	100	100	100	100	100
446	Ethyl bromide	9.10	do	100	100	100	100	100	100	100	100
	do	18.20	do	100	100	100	100	100	100	100	100

TABLE 5.—Results of fumigation tests on weevils in boxes partially filled with grain

[illegible]

[illegible]

Same results obtained for tests Nos. 604, 631, and 632.

EFFECT OF FUMIGATION ON WEEVILS IN THE PRESENCE OF GRAIN IN BOTTLES, BOXES, AND BARRELS

In order to ascertain the action of the compounds as they would be used in practical fumigation work, weevils were placed in pill boxes, with perforations to permit the entrance of the vapor, and the boxes were placed at different levels in grain, usually wheat. The weevils, usually about 10 to the box, were exposed to the action of the compounds for 24 hours, at temperatures from 21° to 32° C.

One series of tests was carried out in large glass bottles of 19 liters capacity (Table 4), another in a wooden box of 100 cubic feet capacity (Table 5), and another in a barrel of 6 cubic feet capacity (Table 6). The fumigant or mixture of fumigants was applied in all these tests by pouring the calculated quantity over the top of the grain and then closing the receptacle. The bottle had a stopper, the barrel had a wooden head, and the box was provided with felt stripping and a tight-fitting cover, which could be clamped down.

(In Tables 4 and 5 the more toxic substance, with its concentration, is given first; the less toxic substance, used principally as a diluent, with its concentration, is given next.)

TABLE 6.—Results of fumigation tests on weevils in grain in barrels (6 cubic feet capacity)

Test No.	Fumigant	Concentration of fumigant	Average mortality	Weevils killed after exposure for 24 hours								
				Bottom of barrel			Middle of barrel			Top of barrel		
				<i>S. oryza</i>	<i>S. granarius</i>	<i>Tribolium</i>	<i>S. oryza</i>	<i>S. granarius</i>	<i>Tribolium</i>	<i>S. oryza</i>	<i>S. granarius</i>	<i>Tribolium</i>
		<i>Lbs. per 1,000 cu. ft.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
386	Carbon tetrachloride (75 per cent) and turpentine (25 per cent).	15.0	17	0	0	95	0	0	25	0	0	30
387	do.....	30.0	14	30	0	100	0	0	0	0	0	0
394	Carbon disulphide....	7.0	52	100	-----	0	50	-----	0	100	-----	60
409	do.....	10.0	87	100	-----	100	100	-----	100	100	-----	0
410A	do.....	10.0	71	100	-----	100	25	-----	0	100	-----	100
1441	do.....	10.0	100	100	-----	100	100	-----	100	100	-----	100
403	{Ethylene bromide....	3.1	100	100	-----	100	100	-----	100	100	-----	100
	{Carbon tetrachloride..	10.0										
431	{Ethylene bromide....	3.1	50	50	-----	50	0	-----	100	0	-----	100
	{Carbon tetrachloride..	10.0										
450	Ethyl bromide.....	9.1	96	100	-----	100	100	-----	100	50	-----	25
456	do.....	18.2	100	100	-----	100	100	-----	100	100	-----	100
	{Epichlorohydrin.....	1.0	100	100	-----	100	100	-----	100	100	-----	100
447	{Carbon tetrachloride..	10.0										
458	{ <i>n</i> -Butyl nitrite.....	2.9	92	50	-----	100	100	-----	100	100	-----	100
	{Carbon tetrachloride..	10.0										

¹ Barrel made as tight as possible in this test.

The insecticidal action of a gas is greatly lessened by the presence of grain, probably because the grain absorbs many vapors in large quantities and because the grain mechanically interferes with the diffusion of the gas throughout the receptacle. For example, in a glass vessel containing nothing but weevils and the vapor of the compound (mixed with air), epichlorohydrin killed 100 per cent of the insects at a concentration equivalent to 0.23 pound per 1,000 cubic feet; when the weevils were planted in wheat, a concentration

of epichlorohydrin equivalent to 2.06 pounds per 1,000 cubic feet, combined with carbon tetrachloride at the rate of 10 pounds per 1,000 cubic feet, did not kill all of the insects in every test.

The compounds consistently causing 100 per cent mortality in the small-scale tests in wheat (Tables 4, 5, and 6) are shown in Table 7.

TABLE 7.—*Most effective fumigants for weevils (based on results in Tables 4, 5, and 6)*

Test No.	Fumigant	Minimum concentration consistently causing 100 per cent mortality of all species after exposure for 24 hours	Test No.	Fumigant	Minimum concentration consistently causing 100 per cent mortality of all species after exposure for 24 hours
		<i>Lbs. per 1,000 cu. ft.</i>			<i>Lbs. per 1,000 cu. ft.</i>
456	Ethyl bromide.....	18.2	439	Ethylene bromide.....	6.2
462	Ethyl bromide.....	4.5		Carbon tetrachloride.....	10.0
629	Carbon tetrachloride.....	10.0	603	Ethylene bromide.....	8.0
630	Ethyl bromide.....	4.5	604	Carbon tetrachloride.....	8.0
615	Carbon disulphide.....	2.2	631	Ethylene bromide.....	5.3
616	Carbon tetrachloride.....	10.0	632	Carbon tetrachloride.....	12.0
	Ethyl bromide.....	4.5	589	Ethylene bromide.....	5.3
611	Carbon disulphide.....	2.2	590	Carbon tetrachloride.....	10.0
612	Carbon tetrachloride.....	10.0	594	Ethylene bromide.....	5.3
	Ethylene bromide.....	5.3	597	Chlorobenzene.....	10.0
599	Ethyl bromide.....	13.2	598	Carbon tetrachloride.....	10.0
600	Ethylene bromide.....	5.3	472	Crotonaldehyde.....	2.9
540	Ethyl bromide.....	1.7		Carbon tetrachloride.....	10.0
545	Methyl formate.....	6.1	445	Ethyl formate.....	2.5
585	Ethyl bromide.....	11.2	546	Carbon tetrachloride.....	10.0
586	Methyl formate.....	3.5	547	Carbon disulphide.....	6.4

With the exception of carbon disulphide, the most economical fumigant at 1924 prices, is the combination of ethyl formate with carbon tetrachloride. (The ethyl acetate-carbon tetrachloride mixture,⁵ which was the most suitable and economical fumigant of all those tested, was not tried on a small scale.)

IN BOX CARS

Many tests were also carried out in box cars of grain. Weevils in perforated pill boxes (10 in each box) were planted at 10 different levels in the grain in a box car, by putting the boxes in the compartments of a grain sampler, which was then plunged into the grain at an angle of about 45°.

The fumigant was applied to the grain by sprinkling the liquid over the surface from a small sprinkler-top watering can as quickly as possible. The door of the car was then closed and sealed. Twenty-four hours later the pill boxes were withdrawn and the number of dead weevils was determined (Table 8). (The more toxic substance, with its concentration, is given first; the less toxic substance, used principally as a diluent, with its concentration, is given next in Table 8.)

⁵ The use of ethyl acetate and ethyl acetate-carbon tetrachloride mixture was suggested by R. C. Roark.

TABLE 8.—Results of fumigation tests on weevils in wheat in box cars

Date	Mean temperature	Relative humidity (noon)	Fumigant			Average mortality	Insects killed at different levels ² after exposure for 24 hours												
			Material	Concentration	Material		Concentration	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10		
								<i>Lbs. per 1,000 cu. ft.</i>	<i>Lbs. per 1,000 cu. ft.</i>	<i>P. cd.</i>	<i>P. cd.</i>	<i>P. cd.</i>	<i>P. cd.</i>	<i>P. cd.</i>	<i>P. cd.</i>	<i>P. cd.</i>	<i>P. cd.</i>	<i>P. cd.</i>	<i>P. cd.</i>
1923	°F.		Ethylene bromide	13.4		<i>Lbs. per 1,000 cu. ft.</i>													
Sept. 13	71		do.	10.5		Carbon tetrachloride	5.0												
Do.	71		do.	8.0		do.	12.0												
June 14	72		do.	8.0		do.	12.0												
Do.	72																		
1922																			
Sept. 13	70					do.	7.0												
Do.	70					do.	14.0												
Do.	70					do.	21.0												
Sept. 19	65					do.	14.0												
Sept. 20	64					do.	21.0												
Oct. 16	79					do.	30.0												
Oct. 31	73		Tetrachloroethane	4.5															
Sept. 1	70		do.	7.0															
Sept. 6	83		do.	16.1															
Sept. 12	72		do.	7.0		Carbon tetrachloride	7.0												
Sept. 19	65		do.	7.0		do.	6.0												
Sept. 20	64		do.	6.3		do.	6.3												
Aug. 31	73		Monochlorobenzene	6.5		do.	6.5												
Sept. 1	70		do.	11.1		do.	11.1												
Sept. 12	72		do.	9.8		do.	9.8												
Sept. 14	74		do.	15.0		do.	15.0												
Oct. 6	79		do.	15.0		do.	15.0												
Do.	79		do.	15.0		do.	15.0												
Nov. 9	50		do.	15.0		do.	15.0												
Do.	50		do.	15.0		do.	15.0												
1923																			
June 13	64		Methyl formate	4.0		Ethyl bromide	11.2												
Do.	64		Ethyl formate	6.4		do.	13.6												
Do.	64		do.	8.8		do.	18.5												
Sept. 25	74		do.	12.1		Carbon tetrachloride	12.1												
Sept. 28	72		Commercial (85%) ethyl acetate	11.8															
Do.	72		do.	15.0															
Sept. 25	74		do.	15.1		Carbon tetrachloride	15.1												
Do.	65		do.	10.0		do.	20.0												

Many of the fumigants and combinations of fumigants which operated successfully in glass jars and in the presence of wheat in bottles, boxes, and barrels gave disappointing results when used on a large scale. A mixture, in equal proportions by weight, of ethylene bromide and carbon tetrachloride, used at the rate of 16 pounds per 1,000 cubic feet, was successful when applied to weevils in wheat in a box, but this mixture, even with the addition of 50 per cent more carbon tetrachloride, was ineffective when used in box cars. This is probably explained by the facts that in a box car the weevils may be in the grain at a much greater depth than in a small box or barrel and that the grain is much more tightly packed. Also, a box car is not a tight container and the vapors of the fumigant may not be long retained.

The most successful fumigants used in the box-car tests were ethyl formate in combination with carbon tetrachloride (12.1 pounds each per 1,000 cubic feet) and ethyl acetate (12.5⁶ pounds per 1,000 cubic feet) in combination with carbon tetrachloride (25 pounds per 1,000 cubic feet).

FIRE HAZARD FROM FUMIGANTS

The vapor pressures of ethyl acetate and carbon tetrachloride are very close for all temperatures up to their boiling points (Table 9, Fig. 1).

TABLE 9.—Vapor pressures of ethyl acetate and carbon tetrachloride

Temperature	Observed vapor pressure ¹		Temperature	Observed vapor pressure ¹	
	Ethyl acetate ²	Carbon tetrachloride ³		Ethyl acetate ²	Carbon tetrachloride ³
° C.	mm.	mm.	° C.	mm.	mm.
-20	6.55	9.92	40	186.20	210.90
-10	12.95	18.81	50	282.20	309.00
0	24.30	33.08	60	415.40	439.00
10	42.70	55.65	70	596.30	613.80
20	72.80	89.55	80	832.70	836.35
30	118.70	139.60			

¹ Sydney Young. The vapor-pressures, specific volumes, heats of vaporization, and critical constants of 30 pure substances. *In* Sci. Proc. Roy. Dublin Soc., n. s. (1909-10), 12:374-443.

² Boiling point at 760 millimeters, 77.15° C.

³ Boiling point at 760 millimeters, 76.75° C.

⁴ Calculated.

A mixture of 3 volumes of carbon tetrachloride and 2 volumes of ethyl acetate (equivalent to 72.5 per cent carbon tetrachloride and 27.5 per cent ethyl acetate by weight) is noninflammable at ordinary temperatures. Moreover, in this mixture the vapors of the two components tend to separate but very slightly, thus making the mixture safe from fire hazard.

On the other hand, carbon disulphide has a much higher vapor pressure than carbon tetrachloride at ordinary temperatures, thus making mixtures of these compounds unsafe. The experiments of the Underwriters Laboratories at Chicago (Grain Dealers Journal, December 10, 1921, vol. 47, p. 798) show that a mixture of 75 per cent carbon tetrachloride and 25 per cent carbon disulphide by vol-

⁶ A mixture of ethyl acetate and carbon tetrachloride containing 33½ per cent by weight of the acetate will flash slightly at ordinary temperatures but will not continue to burn.

ume (equivalent to 79.1 per cent and 20.9 per cent by weight) gives off a highly inflammable vapor. The use of such a mixture to kill weevils or other insects is condemned as dangerous.

A mixture of carbon tetrachloride and carbon disulphide containing as little as 5 per cent by volume of carbon disulphide will flash at 20° C., although it will not continue to burn.

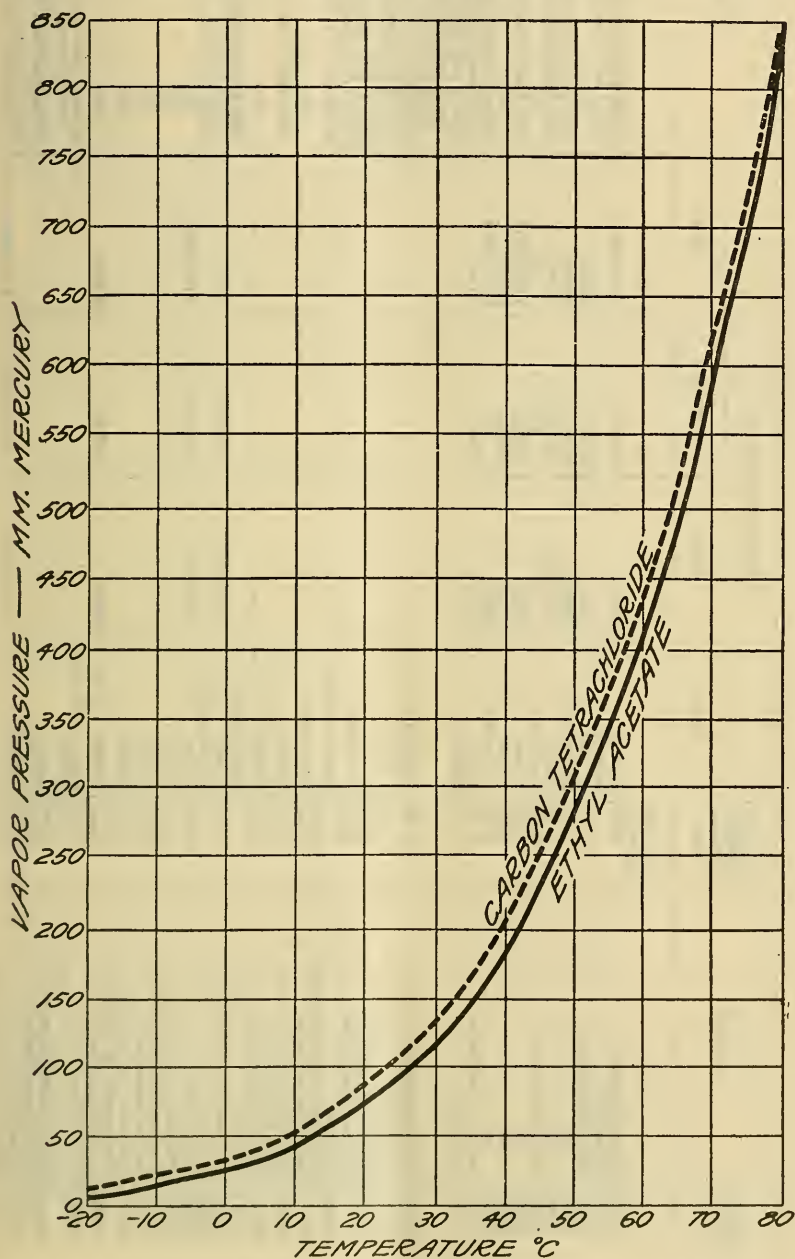


FIG. 1.—Vapor pressures of ethyl acetate and carbon tetrachloride (Table 9).

TABLE 10.—Results of milling tests with wheat exposed to fumigants

Sample No.	Fumigant	Concentration of fumigant	Odor of fumigant on				Remarks
			Wheat	Bran	Shorts	Flour	
8687	Tetrachloroethane	Lbs. per 1,000 cu. ft.	Slight	Strong	Slight	Very slight	Milled soft; flour creamy.
8697	Untreated	4.60	Natural	None	None	None	Milled soft; flour white.
8698	Tetrachloroethane	4.60	do	None	None	None	Do.
8699	do	7.30	Very strong	Strong	Slight	Slight	Milled soft; flour slightly creamy.
8700	do	7.30	Strong	Very slight	Very slight	None	Milled granular; flour creamy white.
8704	Monochlorobenzene	2.90	Very slight	do	do	do	Do.
8688	do	5.85	Strong	Strong	Strong	Very slight	Milled soft; flour white.
8702	do	5.85	do	do	Slight	Slight	Do.
8703	do	2.90	Very slight	Slight	do	Very slight	Milled granular; flour creamy white.
8701	Carbon tetrachloride	10.00	Slight	None	None	None	Milled granular; flour slightly creamy.
10285	Untreated		Natural	None	None		Milled soft (very dry); flour white; grain badly damaged by Angoumois grain moth.
10286	Ethylene bromide	13.40	Very slight				Milled soft (very dry); grain damaged by moth.
10287	Untreated		Natural				Milled soft; flour white; grain damaged by moth.
10288	Ethylene bromide	10.5	Very slight				(Milled soft; flour white (very dry); grain damaged by moth.
10376	Carbon tetrachloride	5.0	Slight garlicky				Milled soft and dry; flour gray.
10377	Ethyl acetate (85 per cent)	15.10	Very slight				Do.
10378	Carbon tetrachloride	15.10	Natural				Do.
10379	Ethyl formate	12.10	Strong				Milled soft; flour white.
10433	Carbon tetrachloride	12.10	Slight garlicky				Do.
10434	Ethyl acetate (85 per cent)	15.00	Strong	Noticeable	Noticeable	None	Milled soft; flour specky white.
10435	Untreated	11.80	Slight garlicky	Noticeable	Noticeable	Noticeable	Milled soft; flour white.
10436	Ethyl acetate	11.80	Strong	Noticeable	Noticeable	Do.	Do.
10455	Untreated	12.50	Natural				Do.
10456	Ethyl acetate (85 per cent)	25.00	Strong				Do.
10457	Carbon tetrachloride	25.00	Natural				Do.
10458	Ethyl acetate (85 per cent)	10.00	Strong	Slight	Slight	Slight	Do.
10459	Carbon tetrachloride	20.00	Musty and garlicky.				Milled granular; flour slate gray; cockles present.
10460	Ethyl acetate (85 per cent)	5.00	Strong				Milled granular; flour slate gray.
10536	Carbon tetrachloride	10.00	Garlicky				Milled soft; flour white.
	Untreated						

10537	{Ethyl acetate (99 per cent)----- {Carbon tetrachloride-----	12.50 25.00	{Strong-----	Very slight-----	Very slight-----	Milled soft; flour creamy white. Milled soft; flour white.
10886	{Ethyl acetate (new process)----- {Carbon tetrachloride-----	15.0 30.0	{Natural-----	-----	-----	Do.
10867	{Ethyl acetate (old process)----- {Carbon tetrachloride-----	15.0 30.0	{Slight-----	-----	-----	Do.
10868	{Ethyl acetate (new process)----- {Carbon tetrachloride-----	12.5 25.0	{Nearly natural-----	-----	-----	Do.
10869	{Ethyl acetate (old process)----- {Carbon tetrachloride-----	12.5 25.0	{Natural-----	-----	-----	Do.
10870	Untreated-----	-----	do-----	-----	-----	Do.
10871	Ethyl acetate (old process)-----	30.0	do-----	-----	-----	Do.
10872	Carbon tetrachloride-----	60.0	do-----	-----	-----	Do.
10873	Untreated-----	-----	do-----	-----	-----	Do.
11023	do-----	-----	do-----	-----	-----	Milled soft; flour gray white. Milled soft; flour creamy white.
11024	{Ethyl acetate (new process)----- {Carbon tetrachloride-----	15.0 30.0	{Very faint; no odor noticeable while milling. do-----	-----	-----	Milled soft; flour white.
11025	{Ethyl acetate (old process)----- {Carbon tetrachloride-----	15.0 30.0	do-----	-----	-----	Do.
11026	{Ethyl acetate (commercial, 85 per cent).----- {Carbon tetrachloride-----	13.0 30.0	{Very noticeable-----	-----	-----	Do.
11027	{Ethyl acetate (99 per cent)----- {Carbon tetrachloride-----	13.0 30.0	do-----	-----	-----	Do.

TABLE 11.—Results of baking tests with flour from fumigated wheat

Sample No.	Fumigant	Concen- tration of fumigant	Absorp- tion	Volume of loaf	Weight of loaf	Color of loaf	Texture of loaf	Crumb of loaf	Remarks
		<i>Lbs. per 1,000 cu. ft.</i>	<i>Per cent</i>	<i>Cc.</i>	<i>Grams</i>				
8687	Tetrachloroethane	4.60	52.1	2,030	483	52.0	85.5	Very gray	Strong odor of fumigant in mixing; garlic odor only in hot and cold loaf.
8688	Monochlorobenzene	5.85	52.1	2,200	484	78.0	92.0	Gray	Do.
8697	Untreated	51.8	51.8	2,130	478	91.0	92.0	Slight cream	No odor of fumigant in mixing; very slight odor in hot loaf but none in cold; flavor normal.
8698	Tetrachloroethane	4.60	52.6	2,090	482	89.5	91.0	Creamy gray	Strong odor in mixing; slight odor in hot loaf but none in cold; flavor of fumigant.
8699	do	7.30	52.4	2,090	481	88.5	88.5	Dark cream	Strong odor in mixing; slight odor in hot loaf but none in cold; flavor of fumigant.
8700	do	7.30	53.5	2,130	484	90.0	92.0	Creamy gray	Very strong odor of fumigant in mixing and in hot loaf but none in cold.
8701	Carbon tetrachloride	10.00	52.6	2,120	485	91.0	92.0	Slight cream	No odor of fumigant in mixing nor in hot or cold loaf; very slight flavor of fumigant.
8702	Monochlorobenzene	5.85	52.4	2,070	482	87.0	87.5	Dark cream	Strong odor of fumigant in mixing; very slight odor in both hot and cold loaf; slight flavor of fumigant.
8703	do	2.90	53.2	2,090	492	90.5	90.0	Slight cream	Strong odor of fumigant in mixing and in hot loaf; slight odor in cold loaf; strong flavor.
8704	do	2.90	53.2	2,120	492	92.0	93.0	do	Very slight odor in mixing and in hot and cold loaf; very slight flavor.
10285	Untreated	13.40	54.1	1,930	483	82.5	88.0	Dark creamy gray	
10286	Ethylene bromide	54.7	54.7	1,930	485	84.0	83.3	do	
10287	Untreated	54.4	54.4	1,940	497	86.3	91.5	Creamy gray	
10288	Ethylene bromide	10.50	55.3	2,070	485	85.0	91.3	do	
10376	Untreated	15.10	55.3	2,030	486	82.0	88.0	Very dark gray	Odor of garlic in hot loaf.
10377	Ethyl acetate (85 per cent)	15.10	55.0	2,060	485	81.5	89.3	do	Odor of fumigant in hot loaf but not in cold.
10378	Carbon tetrachloride	12.10	55.0	1,990	486	82.8	87.8	Dark creamy gray	
10379	Untreated	12.10	54.7	2,020	473	81.5	88.3	Very dark creamy gray	
10433	Ethyl formate	12.10	57.6	1,920	498	82.0	89.3	Dark gray	
10434	Untreated	15.00	57.6	1,980	503	85.0	90.3	do	
10435	Ethyl acetate (85 per cent)	11.80	58.8	2,030	499	87.5	91.3	Gray	Odor of fumigant in dough and slight odor in hot loaf.
10436	Untreated	11.80	58.8	1,960	497	87.0	91.0	do	Slight odor of fumigant in dough.
10455	Untreated	25.00	55.6	1,920	488	82.0	87.5	do	Strong odor of garlic in hot loaf and slight odor in cold loaf.
10456	Ethyl acetate (85 per cent)	12.50	56.2	1,860	483	81.5	87.0	Slight creamy gray	Slight odor of fumigant in dough; odor of garlic in hot loaf.
10457	Carbon tetrachloride	25.00	57.1	2,110	490	88.0	91.5	Creamy gray	

10458	{ Ethyl acetate (\$5 per cent)	{ 10.00	59.1	2,100	501	88.8	90.8	...do....	Very slight odor of fumigant in hot loaf.
10459	{ Carbon tetrachloride	{ 20.00	57.6	1,970	496	4.5	87.0	Black purple	Putrid odor in dough and hot loaf.
10460	{ Ethyl acetate (\$5 per cent)	{ 5.00	57.1	1,930	492	3.0	87.5	...do....	Do.
10536	{ Carbon tetrachloride	{ 10.00	56.2	2,090	490	89.3	91.8	Gray	
10537	{ Untreated	{ 12.50	57.4	2,160	488	88.0	92.3	...do....	
10866	{ Ethyl acetate (99 per cent)	{ 25.00	62.1	2,000	510	82.8	86.8	{ Very dark creamy	No odor of fumigant in hot or cold loaf; flavor normal.
10867	{ Carbon tetrachloride	{ 30.00	63.2	1,990	515	87.5	88.5	gray.	Do.
10868	{ Ethyl acetate (old process)	{ 30.00	62.9	2,000	513	88.3	88.0	Creamy gray	Do.
10869	{ Carbon tetrachloride	{ 25.00	62.6	2,070	512	88.0	87.8	...do....	Do.
10870	{ Ethyl acetate (new process)	{ 25.00	63.2	1,990	510	87.5	87.0	...do....	Do.
10871	{ Carbon tetrachloride	{ 30.00	62.9	2,030	509	89.5	87.5	...do....	Do.
10872	{ Ethyl acetate (old process)	{ 60.00	62.9	2,090	510	89.0	89.0	Dark creamy gray	Do.
10873	{ Carbon tetrachloride	{ 60.00	62.4	2,010	509	88.5	90.0	Creamy gray	Odor and flavor normal
11023	{ Untreated	{ 61.5	61.5	1,880	512	80.0	86.3	Very dark cream	Do.
11024	{ Ethyl acetate (new process)	{ 15.00	60.9	2,060	510	80.0	81.0	Dark creamy gray	{ No odor of fumigant in hot or cold loaf; flavor normal.
11025	{ Carbon tetrachloride	{ 30.00	61.2	1,960	514	81.5	85.8	...do....	Do.
11026	{ Ethyl acetate (old process)	{ 15.00	60.9	1,990	514	82.0	85.5	...do....	Distinct odor of fumigant in hot loaf.
11027	{ Carbon tetrachloride	{ 30.00	60.6	2,040	516	81.8	85.8	Gray	Slight odor of fumigant in hot loaf.
	{ Ethyl acetate (commercial) (85 per cent)	{ 15.00							
	{ Carbon tetrachloride	{ 30.00							
	{ Ethyl acetate (99 per cent)	{ 15.00							
	{ Carbon tetrachloride	{ 30.00							

EFFECT OF FUMIGATION ON MILLED AND BAKED PRODUCTS

The results of the milling and baking tests on wheat and rye treated with various fumigants are given in Tables 10, 11, 12, and 13.

TABLE 12.—Results of milling tests with rye exposed to fumigants

Sample No.	Fumigant	Concentration of fumigant	Odor of fumigant on grain
		<i>Lbs. per 1,000 cu. ft.</i>	
10073	Untreated		Natural.
10074	{Methyl formate	4.0	Do.
	{Ethyl bromide	11.2	
10075	{Ethylene bromide	8.0	Do.
	{Carbon tetrachloride	12.0	
10076	{Ethyl formate	8.8	Do.
	{Ethyl bromide	18.5	
10077	Untreated		Do.
10078	do		Do.
10079	{Ethylene bromide	8.8	None.
	{Carbon tetrachloride	12.0	
10080	Untreated		Natural.
10081	{Ethyl formate	6.4	
	{Ethyl bromide	13.6	Do.
10082	{Ethyl bromide	4.5	
	{Carbon disulphide	2.2	Do.
	{Carbon tetrachloride	10.0	

TABLE 13.—Results of baking tests with flour from fumigated rye¹

Sample No.	Fumigant	Concentration of fumigant	Absorption	Volume of loaf	Weight of loaf	Color of loaf	Texture of loaf
		<i>Lbs. per 1,000 cu. ft.</i>	<i>Per cent</i>	<i>Cc.</i>	<i>Grams</i>		
10073	Untreated		51.5	1,630	462	73.0	90.8
10074	{Methyl formate	4.00	51.8	1,720	485	74.0	90.3
	{Ethyl bromide	11.20					
10075	{Ethylene bromide	8.00	51.5	1,800	488	75.5	91.8
	{Carbon tetrachloride	12.00					
10076	{Ethyl formate	8.80	51.8	1,740	486	73.0	90.3
	{Ethyl bromide	18.50					
10077	Untreated		51.8	1,710	483	70.8	89.3
10078	do		51.8	1,730	483	71.5	89.5
10079	{Ethylene bromide	8.00	51.8	1,730	485	75.0	91.0
	{Carbon tetrachloride	12.00					
10080	Untreated		52.1	1,760	484	72.5	90.5
10081	{Ethyl formate	6.40	52.1	1,710	479	73.0	89.5
	{Ethyl bromide	13.60					
10082	{Ethylene bromide	4.50	51.8	1,730	485	70.8	87.5
	{Carbon disulphide	2.20					
	{Carbon tetrachloride	10.00					

¹In all the tests the crumb of the loaf was gray. No odor of the fumigant was detected in samples 10074, 10076, 10081, or 10082. A slight odor of the fumigant in the dough, but none in the loaf, either hot or cold, was detected in samples 10075 and 10079.

Tetrachloroethane and monochlorobenzene gave a disagreeable odor to the flour and bran and other by-products. This disagreeable odor in the flour was carried through to the finished loaf. Ethyl bromide, ethylene bromide, carbon tetrachloride, and ethyl formate left very little or no odor in the flour. If present in the flour, it was completely volatilized during baking, giving a loaf free from foreign odor. The commercial grades of ethyl acetate, both the 85 per cent and the 99 per cent, left a noticeable odor in the grain, bran, shorts, and flour; this odor appeared even in the hot loaf. The

"old process" and "new process" grades of ethyl acetate completely volatilized from the grain, so that no odor was noticeable in the process of milling, and the loaf, hot or cold, had only the natural odor and flavor (samples 11024 and 11025 in Tables 10 and 11).

The suitability of a sample of ethyl acetate for fumigating grain should be determined by the following test: Wet a sheet of filter paper (11-centimeter diameter is a convenient size) with the ethyl acetate, and allow it to evaporate, noting the odor from time to time. No foreign odor should be present, and the liquid should volatilize completely without leaving any odor. The carbon tetrachloride to be mixed with the ethyl acetate should be similarly tested, and should likewise be free from odoriferous constituents of low volatility. The presence of sulphur compounds in carbon tetrachloride is particularly objectionable because they give a garlicky odor to the fumigated grain. Ethyl acetate and carbon tetrachloride of a grade which satisfies this test are now commercially available in large quantities at a price but slightly higher than that asked for the commercial grades.

ADDITIONAL FUMIGATION TESTS WITH ETHYL ACETATE AND CARBON TETRACHLORIDE

In August and September, 1924, car fumigation tests were made with a mixture of ethyl acetate and carbon tetrachloride combined in a ratio that would make a noninflammable product at ordinary temperatures. The results are shown in Table 14.

TABLE 14.—*Results of fumigation tests on weevils in wheat in box cars, using a mixture of 40 volumes of ethyl acetate with 60 volumes of carbon tetrachloride*

Date	Mean temperature	Relative humidity (noon)	Concentration	Average mortality ¹	Insects killed at different levels after exposure for 24 hours										Insects in grain ²
					Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10	
	° F.	Per cent	Lbs. per 1,000 cu. ft.	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1924															
Aug. 26	78	68	30	80	100	100	50	50	50	100	50	100	100	100	100
26	78	68	40	96	100	100	100	100	100	80	80	100	100	100	(³)
27	78	41	40	99	100	100	100	100	100	100	90	100	100	100	100
27	78	41	40	99	100	100	100	100	100	90	100	100	100	100	100
27	78	41	40	100	100	100	100	100	100	100	100	100	100	100	99
28	80	61	50	100	100	100	100	100	100	100	100	100	100	100	100
Sept. 3	66	53	40	100	100	100	100	100	100	100	100	100	100	100	100
3	66	53	40	100	100	100	100	100	100	100	100	100	100	100	100
4	66	45	40	86	100	100	100	100	100	80	90	90	80	20	100
6	60	41	40	98	100	100	100	100	100	100	80	100	100	100	(³)
6	60	41	40	97	90	100	90	100	100	100	100	100	100	90	(³)
2	78	51	40	-----	No weevils; sampled for milling and baking tests.										
2	78	51	40	-----	Do.										
2	78	51	40	-----	Do.										
2	78	51	40	-----	Do.										

¹ For insects exposed in pill boxes.

² The grain in all but six of the ears fumigated was moderately infested with weevils. The percentages given in this column represent the kill of this infestation.

³ A few alive in ends of ear.

⁴ Fumigation interrupted when halfway through for 10 or 15 minutes, during which time the car door remained open.

⁵ No weevils.

TABLE 15.—*Results of milling tests with wheat before and after fumigation in box cars with a mixture of 40 volumes of ethyl acetate and 60 volumes of carbon tetrachloride*

Sample No.	Before or after fumigation	Concentration of fumigant	Odor of fumigant on—				Remarks
			Wheat	Bran	Shorts	Flour	
11643	Before	Lbs. per 1,000 cu. ft. 30	Natural.	Natural.	Natural.	Natural.	Milled granular; flour creamy white.
11644	After		Slight.	Very slight.	Very slight.	(¹)	Do.
11649	Before	40	Natural.	Natural.	Natural.	Natural.	Do.
11650	After		Slight.	Very slight.	Very slight.	(¹)	Do.
11641, 11645, 11647	Before	40	Natural.	Natural.	Natural.	Natural.	Milled granular; flour creamy.
11642, 11646, 11648	After		Slight.	Very slight.	Very slight.	(¹)	Milled granular; flour creamy white.
11651	After second fumigation.	(²)	do.	do.	do.	(¹)	Do.
11652, 11663	Before	40	Garlicky ³	Garlicky.	Garlicky.	Garlicky.	Milled soft; flour creamy white.
11653, 11664	After		do ³	do.	do.	do.	Milled granular; flour creamy white.
11662, 11666, 11668	Before	40	Garlicky ³	do.	do.	do.	Milled soft; flour creamy white.
11665, 11667, 11669	After		do ³	do.	do.	do.	Do.
11656	Before	40	Natural.	Natural.	Natural.	Natural.	Milled soft; flour white.
11657	After		do.	do.	do.	do.	Do.
11658	Before	40	Slight.	Very slight.	Very slight.	(¹)	Milled very soft; flour white.
11659	After		do.	do.	do.	do.	Milled soft; flour creamy white.
11660	Before	40	Smut.	Smut.	Smut.	(¹)	Milled granular; flour gray.
11661	After		Slight.	Very slight.	Very slight.	(¹)	Milled granular; flour grayish white.
11654	Before	40	Natural.	Natural.	Natural.	Natural.	Milled granular; flour creamy white.
11655	After		do.	do.	do.	do.	Milled soft; flour white.

¹ Odor of fumigant in flour so slight as to be detected only by comparison with normal flour. The odor left by this fumigant is almost indistinguishable from that present in slightly fermented grain and is not objectionable from the standpoint of the baker because no odor remains in the bread baked from this flour.

² This car of wheat was fumigated with the mixture at the rate of 40 pounds per 1,000 cubic feet; two days later the same wheat was again fumigated at the rate of 50 pounds per 1,000 cubic feet.

³ This wheat contained some seed of garlic, the odor of which was so pronounced that it masked all other odors.

TABLE 16.—Results of baking tests with flour from wheat before and after fumigation in box cars with a mixture of 40 volumes of ethyl acetate and 60 volumes of carbon tetrachloride

Sample No.	Before or after fumigation	Concentration of fumigant	Absorption	Volume of loaf	Weight of loaf	Color of loaf	Texture of loaf	Crumb	Remarks
		<i>Lbs. per 1,000 cu. ft.</i>	<i>Per cent</i>	<i>Cc.</i>	<i>Grams</i>				
11643	Before	30	53.8	1,620	484	84	85	Dark cream	Flavor normal; odor normal.
11644	After	30	54.1	1,810	486	84	87.3	do	Do.
11649	Before	40	56.8	2,080	497	85.3	88	Dark creamy gray	Do.
11650	After	40	56.5	2,120	496	85.3	88.8	do	Do.
11641	Before	40	57.4	1,950	492	84.8	87.5	do	Do.
11642	After	40	57.1	2,160	491	85	87.3	do	Do.
11645	Before	40	56.2	2,060	492	84.3	87	do	Do.
11646	After	40	56.8	2,130	493	84.3	87.3	do	Do.
11647	Before	40	56.8	2,140	497	85.3	88	do	Do.
11648	After	40	56.5	2,150	492	86.5	89	do	Do.
11651	After second fumigation.	(¹)	57.1	2,080	504	85.5	88.8	do	Do.
11652	Before	40	51.5	2,140	480	82.5	90.3	Gray	Garlic in dough and cold bread.
11653	After	40	51.5	2,040	479	82.8	90.3	do	Do.
11653	Before	40	51.5	1,940	481	85.3	90.8	Dark creamy gray	Flavor normal; odor normal.
11654	After	40	51.5	1,990	480	85	90.5	Dark cream	Do.
11662	Before	40	51.5	2,010	482	83	88.5	do	Do.
11665	After	40	51.5	2,010	481	85.5	90.5	do	Do.
11666	Before	40	51.5	1,530	485	78.5	20	Very dark creamy gray	Do.
11667	After	40	51.5	1,490	483	75.8	20	do	Do.
11668	Before	40	51.5	2,010	486	85	90.5	Dark cream	Do.
11669	After	40	51.5	2,000	477	80	80.3	Very dark creamy gray	Do.
11656	Before	40	52.4	1,700	476	82	81	Dark cream	Do.
11657	After	40	52.9	1,850	488	85.5	89.5	Dark creamy gray	Do.
11658	Before	40	52.9	2,050	488	86	90.3	Creamy gray	Do.
11659	After	40	53.5	2,080	488	86	90.8	do	Do.
11660	Before	40	52.4	2,080	485	39	90.3	Very gray	Do.
11661	After	40	52.9	2,230	485	59	92	Gray	Do.
11654	Before	40	52.9	1,900	490	84.5	88	Creamy gray	Do.
11655	After	40	52.9	1,970	492	89.3	91.3	Light cream	Do.

¹ This car of wheat was fumigated with the mixture at the rate of 40 pounds per 1,000 cubic feet; 2 days later the same wheat was again fumigated at the rate of 50 pounds per 1,000 cubic feet.

With the exception of four cars fumigated for milling and baking tests, the rice weevil (*S. oryza*) was the test insect used in the pill boxes. Furthermore, the grain in all but two of the cars was moderately infested with weevils. The results given in the last column in Table 14 show the percentage kill of this natural infestation.

The results of the car fumigation reported in Table 14 confirm those reported in Table 8.

With the exception of one case, where fumigation was interrupted, all fumigations with a mixture of 40 per cent by volume of ethyl acetate and 60 per cent by volume of carbon tetrachloride, in which not less than 40 pounds of the mixture per 1,000 cubic feet of inclosed space was used, gave satisfactory kills.

The results of the milling tests with the wheat fumigated in these box-car experiments are shown in Table 15; the results of the baking tests with flour made from this wheat are shown in Table 16. The data indicate that both the flavor and odor of bread baked from flour made from wheat fumigated in box cars with a mixture of 40 volumes of ethyl acetate and 60 volumes of carbon tetrachloride, at the rate of 40 pounds per 1,000 cubic feet, are normal.

EFFECT OF ETHYL ACETATE-CARBON TETRACHLORIDE FUMIGATION ON GERMINATION OF SEEDS

The seeds of wheat, barley, rye, winter oats, and corn in tightly closed bell jars were exposed to the vapor of ethyl acetate and carbon tetrachloride at a concentration of 40 pounds per 1,000 cubic feet for 24 hours. The percentage germination before and after fumigation is shown in Table 17.

TABLE 17.—Effect of ethyl acetate-carbon tetrachloride fumigation on germination of seeds

Seed	Germination		Seed	Germination	
	Before fumigation	After fumigation		Before fumigation	After fumigation
	<i>Per cent</i>	<i>Per cent</i>		<i>Per cent</i>	<i>Per cent</i>
Wheat.....	83	85	Winter oats.....	95	93
Barley.....	97	98	Corn.....	97	94
Rye.....	89	90			

The results in Table 17 show that exposure at 31° C. in a tight container for 24 hours to the fumes of a 40-60 mixture (by volume) of ethyl acetate and carbon tetrachloride at the rate of 40 pounds per 1,000 cubic feet does not injure the germinating power of wheat, barley, rye, winter oats, and corn. The grain would not be subjected to as severe a test in ordinary box cars.

SUMMARY

The action of more than 100 organic compounds on weevils was tested under conditions permitting a control of the factors of concentration, time, and humidity, and with observations of the temperature.

The following 30 compounds were more toxic to the rice weevil (*S. oryza* L.) than carbon disulphide: Two out of 8 bromides tested;

3 out of 15 chlorides tested; the only iodide tested; 1 alcohol out of 8 alcohols and phenols tested; 3 out of 4 aldehydes tested; 2 out of 4 ketones tested; both of the chlorine-substituted ketones tested; 1 of the 2 chlorohydrins tested; 5 out of 9 esters tested; 4 out of 12 sulphur compounds tested; 1 nitrile out of 5 nitriles and isonitriles tested; both of the nitrites tested; 2 out of 8 amines tested; and pyridine.

The relative toxicity of the different classes of compounds can not be given because the low volatility of several of those tested gave only very low vapor concentrations. As a class, the hydrocarbons showed the lowest insecticidal efficiency, not one of the eight tested equalling carbon disulphide in fumigating power. The most effective fumigant in the glass-jar tests was epichlorohydrin, which killed the rice weevil at a concentration of 0.09 per cent, equivalent to 0.23 pound per 1,000 cubic feet. It was, however, an unsatisfactory fumigant in the presence of grain.

There is no constant relationship between the boiling points and the lethal concentrations of the compounds killing 100 per cent of the rice weevils after exposure for 24 hours.

A much greater concentration of fumigant is required to kill weevils in wheat than to kill those exposed directly to the vapors in glass jars. A still higher concentration is necessary to kill weevils in wheat in box cars. Ethyl formate and ethyl acetate were the only promising fumigants for grain in box cars. The acetate, however, costs only about one-third as much as the formate.

Odoriferous constituents of low volatility from commercial grades of ethyl acetate (both the 85 per cent and the 99 per cent grades) are carried through from the fumigated wheat to the flour, and even to the bread baked from it. A pure grade of ethyl acetate, however, leaves practically no odor in the fumigated grain or in the bran or shorts made from the grain, and none in the flour or in the bread baked from the flour.

The insecticidal efficiency of ethyl acetate under practical fumigating conditions is increased by the addition of carbon tetrachloride.

The most effective fumigant, other than carbon disulphide, against weevils in wheat, in grain cars, under practical fumigating conditions, is a mixture of about 40 volumes of ethyl acetate and about 60 volumes of carbon tetrachloride. It is noninflammable at ordinary temperatures. The proper dosage of this mixture for fumigating box cars is about 45 pounds per 1,000 cubic feet. Both the ethyl acetate and the carbon tetrachloride must be tested to make sure that they are free from odoriferous constituents of low volatility before they are used in grain fumigating.

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BEHAVIOR OF COTTON PLANTED AT DIFFERENT DATES IN WEEVIL- CONTROL EXPERIMENTS IN TEXAS AND SOUTH CAROLINA

By

W. W. BALLARD, Senior Scientific Aid, and D. M. SIMPSON, Assistant Agronomist
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Bureau of Plant Industry

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INTRODUCTION

More information is needed on the growth and fruiting habits of early and late planted cotton in relation to cultural control of the boll weevil. In the season of 1923 comparisons were made of the behavior of early and late plantings in Texas and South Carolina, and differences were shown in the rates of growth and the fruiting habits of the plants.

A more rapid formation of nodes during the seedling stage of the plants was found to occur in the later plantings, resulting in a shorter interval between the date of planting and the appearance of the first floral bud. The fruiting capacity of late-planted cotton was found to equal and in some cases to exceed that of the early-planted cotton. The large number of floral buds produced in later plantings was due to the fact that more nodes were produced on the lower fruiting branches. Also, slightly larger numbers of flowers were recorded on the late-planted cotton, although the early plantings produced a larger number of flowers during the first part of the flowering period.

The experiments were made in three places—San Antonio, Tex., Charleston, S. C., and Gainesville, Fla. The object of having similar tests in three widely separated parts of the Cotton Belt was to secure comparative data of plant development under different soil and climatic conditions. The experiments consisted of side-by-side comparisons of cotton planted on four different dates. An

interval of 10 days between plantings was used in South Carolina and Florida and 7 days in Texas.

As these experiments were conducted under boll-weevil conditions, measures were taken to protect the early plantings from infestation by overwintered weevils. Uncontrolled infestation in the early plantings would have caused excessive infestation in the adjacent later plantings and would have prevented comparable data being obtained from the different plantings. The method of weevil control was by removal of squares and the application of poison after most of the weevils had emerged from hibernation.

At San Antonio, Tex., it was only necessary to apply poison to the two later plantings, those of May 5 and May 12, as these plantings had not reached the fruiting stage at the time squares were removed from the early plantings.

A separate late planting was made at San Antonio on May 12 in order to compare the development and fruiting habits of cotton in rows that were left unthinned with rows that were thinned to two plants in a hill with hills 12 inches apart. This comparison showed that plants left in hills had a larger individual fruiting capacity than the unthinned plants, due to the production of more nodes on the fruiting branches. But this difference in the fruiting capacity of individual plants was counterbalanced by the greater number of plants in the unthinned rows. More flowers were recorded from the unthinned cotton, and a marked difference in the rate of flowering occurred during the first half of the flowering period, the unthinned rows producing flowers at almost twice the rate of the rows that were thinned.

No trace of weevil infestation was found in this separate late-planted field until July 8, after the beginning of the flowering period. Thus, it appeared that the planting of May 12 had been late enough to avoid any infestation from overwintered weevils in the season of 1923 at San Antonio.

SOIL, CLIMATIC, AND WEEVIL CONDITIONS AT SAN ANTONIO, TEX.

The United States San Antonio Field Station is located about 5 miles south of the city. The soil on the farm is typical of a large part of the cultivated land in that region and is technically described as Houston clay loam. It is of high natural fertility and is fairly retentive of moisture. The subsoil is a coarse gravel, which affords good drainage but limits the water-storage capacity of the soil.

The annual precipitation is variable, ranging from 13 to nearly 40 inches. The average annual rainfall over a period of 15 years is about 26 inches. Although the precipitation is usually sufficient for cotton production, the distribution is very irregular. Periods of excessive rainfall are frequently followed by protracted periods of hot dry weather which deplete the soil moisture and cause serious injury to crops.

The precipitation during the season of 1923, from January 1 to October 1, was 23.47 inches, which was about 4 inches in excess of the 15-year average for the same period. The heaviest monthly rainfall, 6 inches, was recorded in February. Rains occurring during the winter months are often an important factor in this section, as stored moisture in the soil may enable the plants to continue growth

even when surface moisture becomes deficient. June was very dry, with only 0.55 inch of rain. Precipitation during the growing period of cotton was fairly well distributed, but effective rains fell on only six days between May 30 and September 7.

Maximum temperatures during June, July, and August were comparatively high, and the long periods of hot weather between the few good rains resulted in droughty conditions in spite of the apparently adequate precipitation.

The average monthly maximum and minimum temperatures and the monthly precipitation for the season of 1923 are given in Table 1.

TABLE 1.—Average minimum and maximum temperatures and monthly precipitation at San Antonio, Tex., from April to September, 1923

Items of comparison	Jan. to Mar.	Apr.	May	June	July	Aug.	Sept.
Average temperature (° F.):							
Minimum.....		59.3	64.5	72.4	71.2	72.4	70.7
Maximum.....		77.6	89.0	95.4	95.3	97.8	89.4
Precipitation (inches):							
1923.....	9.27	2.93	1.67	.55	3.77	2.50	3.02
Average, 1907 to 1920.....	3.98	3.11	3.09	1.88	2.12	1.87	2.57

Favorable conditions for the hibernation of boll weevils in the San Antonio district are afforded by scattered areas of undeveloped land covered with mesquite and huisache trees and by large fields of Johnson grass. A heavy infestation from overwintered weevils usually occurs in cotton planted in this section. The first new generation of weevils usually appears before the first of July.

Periods of dry weather often restrict the growth of the plants, and the shed squares are exposed to direct sunlight, so that a natural control of the weevils may result from destruction of the larval and pupal stages in the fallen squares. When heavy rainfalls occur during the early stages of plant growth, excessive vegetative development of the plants results, so that the weevils have more protection even though there is dry weather later in the season. There is slight possibility of effective natural control when the plants grow large and the lanes between rows are shaded so as to protect the infested squares.

In the season of 1923 weevils were first found on May 28. Squares were very small at that time, but by the first week in June numerous punctured squares could be seen in all cotton which had reached the fruiting stage. Dry weather throughout the greater part of May and June retarded the growth of the plants. This small size kept the lanes open between the rows and afforded favorable conditions for natural control of weevils by exposing the fallen squares to direct sunlight. Nevertheless, the weevil infestation increased slowly, until by the first of August there were enough weevils to destroy practically all of the squares.

COMPARISON OF SUCCESSIVE ADJACENT PLANTINGS AT SAN ANTONIO

At San Antonio the successive plantings were made on April 19 and 28 and May 5 and 12. The Lone Star variety was used, the seed having been grown on the experiment farm in 1922. The rows were

200 feet in length and were spaced 4.1 feet apart. The location of this test with relation to other cotton plantings on the experiment farm is shown in Figure 1, and the planting diagram of the test is shown in Figure 2.

Conditions were favorable for the germination of the seed in the first three plantings, and good stands were obtained. Dry weather, following rains which occurred during the last week in April, dried out the soil to a considerable depth, and a stand of about 30 per cent resulted from the planting of May 12, the remainder of the seed lying in the ground until germinated by a rain on May 30. The seedlings produced from the seed that germinated first grew rapidly and produced vigorous plants. The moisture supply in the surface soil was inadequate to support growth of the seeds that germinated late, and most of the resulting seedlings died or remained stunted throughout the season.

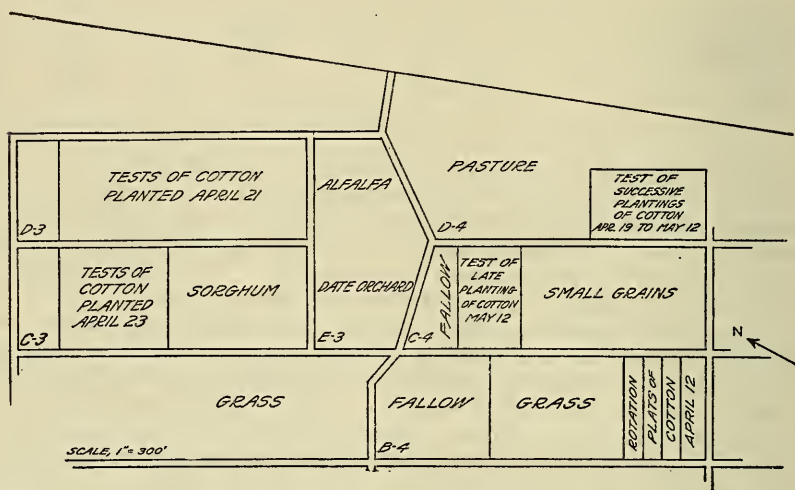


FIG. 1.—Diagram of part of the United States San Antonio Field Station, showing the location of successive plantings and the separate late-planting test of cotton with relation to other cotton plantings

The first three plantings were thinned to two plants in a hill with the hills 12 inches apart. Thinning was done by hand in order to obtain as regular spacing as possible. The fourth planting was not thinned, as the poor stand rendered this unnecessary.

The April 19, April 28, and May 5 plantings were thinned on May 25, June 4, and June 8, respectively. At the time of thinning, the plants in the first two plantings had from five to seven true leaves and averaged about 20 centimeters in height. The plants in the third planting were slightly larger when thinning was done, averaging 22.5 centimeters in height and having from six to eight true leaves.

GROWTH RATE OF SEEDLINGS

In order to compare the rate of development during the seedling stage, the height and number of nodes on 10 representative plants in each planting were recorded when the first floral buds, or squares, appeared. The plants in each planting were examined on June 1 and

at weekly intervals thereafter. While this method did not give the actual date of appearance of the first floral bud on each plant, the beginning of the fruiting stage of the plants may be determined with sufficient accuracy from the first week when the presence of squares was recorded. Table 2 shows the date when squares were first recorded in each planting, together with the average height, number of nodes,¹ and the average number of squares formed.

A more vigorous growth of seedlings in the later plantings is shown by these records. The rate of growth increases with each later planting, the rate of formation of nodes on the axis being more rapid, while the length of the internodes also increases. The faster development of nodes reduces the interval between planting and the appearance of the first squares.

The more rapid formation of nodes on plants of the later plantings probably was due to higher temperatures during the early stages of growth. Seedlings in the later plantings did not encounter cooler weather, which may have checked the growth in earlier plantings.

In comparing the rate of nodal growth of seedlings, the period from germination of the seed to appearance of squares is used. Table 3 gives the date when germination was first noted in each planting, the number of days from germination to the first record of square formation, the average number of axis nodes formed during that period, and the average maximum and minimum temperatures for the same period.

SECTION A SECTION B

10 ROWS. PLANTED APR. 19	
6 ROWS. PLANTED APR. 28	
6 ROWS. PLANTED MAY 5	
8 ROWS. PLANTED MAY 12	
8 ROWS. PLANTED APR. 19	
6 ROWS. PLANTED APR. 28	
6 ROWS. PLANTED MAY 5	
8 ROWS. PLANTED MAY 12	
10 ROWS. PLANTED APR. 19	

FIG. 2.—Diagram of successive plantings of cotton at San Antonio, Tex.

TABLE 2.—Average development of 10 cotton plants at the beginning of the fruiting stage as grown in successive plantings at San Antonio on four different dates

Date planted, 1923	Squares first recorded	Number of days from planting	Height of plants (centimeters)	Number of nodes on main stalk	Average number of squares
Apr. 19.....	June 1	43	21.5	6.5	2.2
Apr. 28.....	June 8	41	23.4	7.1	2.8
May 5.....	do.....	34	22.6	6.2	1.9
May 12.....	June 15	34	24.4	5.9	1.7

¹ All records of the number of nodes on the main stalk are exclusive of the cotyledon node.

TABLE 3.—*Relation of temperature to the development of cotton plants as grown in successive plantings at San Antonio on four different dates*

[The temperatures shown (° F.) cover the period from the date of seed germination to the first appearance of squares]

Date planted, 1923	Date of germination	Number of days to squaring	Number of nodes formed	Average number of days per node	Average temperature	
					Minimum	Maximum
Apr. 19	Apr. 25	37	6.5	5.7	64.4	88.5
Apr. 28	May 4	35	7.1	4.9	66.5	90.8
May 5	May 12	27	6.2	4.4	68.6	92.3
May 12	May 20	26	5.9	4.4	70.7	94.0

It will be noted that the interval between the development of successive nodes decreases when higher temperatures occur during the period from germination to the appearance of squares. The average rate of nodal development during the seedling stage of the April 19 planting was 5.7 days. During this period the average minimum temperature was 64.4° and the average maximum 88.5° F. The May 12 planting averaged 4.4 days per node during the seedling stage of the plants, the average minimum and maximum temperatures having been 70.7° and 94° F., respectively.

DAMAGE BY OVERWINTERED WEEVILS

The extent of weevil infestation in the successive plantings of cotton was determined on June 5 by recording the numbers and percentages of squares that had been attacked by weevils. On June 5 squares were present only on the April 19 planting. Even on this there were only a few large squares, and it was necessary to examine about 200 plants in order to find 100 squares that were regarded as over 10 days old. Records of growth of squares have indicated that a period of about 10 days elapses between the time when a square is first visible and the time when it has reached sufficient size to harbor a weevil larva.²

In block 1 of the April 19 planting, which was located on the south side of the field, 45 per cent of the squares were punctured by weevils. Block 2, in the center of the field, had 20 per cent of the squares punctured, and block 3, on the north side of the field, had 15 per cent of punctured squares.

The heavier infestation in block 1 may have been due to the fact that the field adjoined a Johnson grass pasture on the south. A large part of the weevil emergence probably occurred from this pasture, and a large number of the weevils would doubtless remain in the first cotton where squares were found.

STRIPPING OF FLORAL BUDS OR "SQUARES"

Squares were removed on June 12 from the first and second plantings, and the entire field was poisoned with calcium arsenate. At that time the squares on the third and fourth plantings were below the size for stripping, so that it was necessary only to apply poison.

² Martin, R. D., W. W. Ballard, and D. M. Simpson. Growth of fruiting parts in cotton plants. *In* Jour. Agr. Research, v. 25, p. 202. 1923.

No squares were removed that were less than 10 days old, at which time the involucre of the square was about three-eighths of an inch in length. It was found to be impossible to remove squares smaller than this without breaking the tips of the fruiting branches or injuring the terminal buds of the plants. Records were obtained of the number of squares picked from four rows in the April 19 and April 28 plantings. The number of plants to the row and the number of squares removed from each row are given in Table 4.

TABLE 4.—*Number of squares removed on June 12 from cotton plants of the first and second plantings in rows 200 feet long at San Antonio*

Date planted, 1923	Number of plants to the row	Number of squares removed	Average number of squares to the plant	Date planted, 1923	Number of plants to the row	Number of squares removed	Average number of squares to the plant
Apr. 19-----	392 375 403 387	787 803 823 734	2.0 2.1 2.0 1.9	Apr. 28-----	300 261 285 334	128 146 114 193	0.4 .6 .4 .6

An average of two squares removed from each plant corresponds to the amount of stripping reported in experiments with the stripping method in Florida.³ A difference of nine days in the planting date of the first and second plantings resulted in only one-fourth as many squares being removed from the second planting as from the first. In plantings which were deferred until May 5 and May 12 there was no necessity of square removal to avoid infestation by overwintered weevils.

The average time required for finding and removing squares was 48 minutes per row in the April 19 planting and 22 minutes per row in the planting of April 28, the length of rows being 200 feet. On this basis the time required to strip an acre was estimated at 41 hours for the first planting and 19 hours for the second. At the rate of four days per acre, or even two days, the labor requirement for square stripping is considerable.

Only 2 weevils were found in squares removed from the two blocks of the second planting, while 96 weevils were caught in the three blocks of the first planting. The fact that so few weevils were caught in the second planting is probably due to the smaller number of large squares on the later plants. Weevils which are feeding on the floral bud inside the involucre of large squares are more likely to be caught.

A hundred squares from each row in the April 19 and April 28 plantings were examined, in order to determine the percentage of squares that had been punctured. The records of punctured squares in each block of the first planting gave the following average percentages of infestation: Block 1, 23; block 2, 14; block 3, 12. The first block of the second planting had 9.7 per cent and the second block had 6.5 per cent of the squares punctured.

Calcium arsenate in dry-dust form was applied to the entire field immediately following the removal of squares from the first two

³ Smith, G. D. A preliminary report upon an improved method of controlling the boll weevil. Fla. Agr. Exp. Sta. Bul. 165, 72 p., illus. 1922.

plantings. A hand gun was used in dusting the plants, the poison being applied at the rate of about 8 pounds per acre. It remained on the plants until June 17, when most of it was washed off by a light rain. No further poisoning was attempted during the remainder of the season.

A comparison of the development of plants in the four plantings was made on June 15, three days after squares had been removed and poison applied. Data on the height of plants, the number of nodes on the main stalk, the total number of squares that had been formed to June 15, and the actual number of squares on the plants are presented in Table 5.

TABLE 5.—*Development of cotton plants, showing the average number of squares formed on each plant on June 15 as grown in successive plantings at San Antonio on four different dates*

Date planted, 1923	Height (centimeters)	Number of nodes	Average number of squares on plants	
			Formed to June 15	Remain- ing on June 15
Apr. 19	28.6	11.2	10.6	5.9
Apr. 28	28.0	9.2	6.5	5.1
May 5	27.8	8.6	5.7	5.4
May 12	24.3	5.9	1.7	1.7

The difference between the total number of squares that had been formed by June 15 and the number actually on the plants at that date represents the loss through square removal and shedding. Considerable shedding of very small squares occurred in the April 19 planting, practically all of the squares formed prior to June 1 having been shed by June 8.

WEEVIL INFESTATION AFTER STRIPPING SQUARES

Although the young squares on the first three plantings had developed within a week after stripping and poisoning to a size which would render them susceptible to weevil injury, no indication of infestation was detected for another week, or until June 25. Three small areas of infested plants were observed on that date in widely separated parts of the field.

The absence of weevil infestation for a period of nearly two weeks after stripping and poisoning indicates that the control measures had practically exterminated the weevils present in the field on June 12. It is probable that the slight infestation which was first noted on June 25 resulted from weevils that had emerged from early-punctured squares. Some of the squares on the first planting which had been punctured during the first week in June were shed before the plants were stripped. Some of the squares which had been shed previous to stripping might have been missed by laborers.

Several scattered points of infestation appeared within a few days after the first trace of weevil damage was noted, most of these points occurring in the first planting. Infestation increased slowly, and by the middle of July evidence of weevil injury could be found throughout the field.

Although the field became reinfested with weevils after square removal and poisoning, the degree of infestation was much less than in untreated early-planted fields on other parts of the experiment farm. Possibly a more effective control might have been obtained if the measures had been applied earlier than June 12, as fewer infested squares would have been shed before the square-stripping operation.

PLANT GROWTH DURING THE FRUITING PERIOD

Records of the nodal growth of the cotton plants, the rate of flowering, and the extent of boll shedding were obtained from each of the four plantings. Comparisons of the rate of formation of internodes were obtained from 10 representative plants in each planting, while the flower counts and boll sheds were recorded from 50-foot sections of rows.

The records of plant development following the appearance of squares were obtained from diagrams of the same plants which were used in comparing the rate of growth during the seedling stages. These diagrams were made at weekly intervals throughout the period of fruiting of the plants, the final records having been made on August 11, after growth had practically ceased.

A comparison of the rate of formation of internodes on plants in the successive plantings is shown in Table 6, which gives the average number of nodes on 10 plants of each planting on the date when squares were first recorded and 14, 28, and 56 days later. As the first squares were recorded on different dates, it should be noted that the nodal development of the plants in each planting is compared during similar stages of growth and not on the same dates.

TABLE 6.—*Development of nodes on the main stalk during the fruiting stage of cotton plants grown in successive plantings at San Antonio on four different dates*

Date of planting, 1923	Squares first recorded	Number of nodes at stated intervals after first appearance of squares								Total in- crease	Prob- able error
		Aver- age	14-day interval		28-day interval		56-day interval				
			Actual	In- crease	Actual	In- crease	Actual	In- crease			
Apr. 19.....	June 1	6.5	11.2	4.7	14.8	3.6	18.6	3.8	12.1	±0.15	
Apr. 28.....	June 8	7.0	11.5	4.5	14.9	3.4	18.2	3.3	11.2	±.22	
May 5.....	do.	6.2	10.9	4.7	14.2	3.3	16.9	2.7	10.7	±.37	
May 12.....	June 15	5.9	11.8	5.9	15.1	3.3	18.9	3.8	13.0	±.22	

The average number of nodes produced on the main stalk during the first period of 14 days after the appearance of squares was 4.7, 4.5, and 4.7 nodes, respectively, on plants of the first three plantings. The planting of May 12, however, formed 5.9 nodes during this period. During the second period of 14 days the rate of formation of nodes was much slower, the increase in number of nodes having been 3.6, 3.4, 3.3, and 3.3, respectively. The final period comprised 28 days, but the increase in number of nodes was only 3.8, 3.3, 2.7, and 3.8, or about the same as during the preceding period of 14 days. The total number of nodes formed during the entire period of 56 days after the appearance of the first squares was 12.1 nodes on plants

of the April 19 planting, 11.2 nodes on the April 28 planting, 10.7 nodes on the May 5 planting, and 13 nodes on the May 12 planting.

In order to show the number of nodes on plants in the different plantings on the same dates, the weekly records of nodal development are graphically presented in Figure 3. These curves show that the nodal development of the first three plantings was nearly parallel throughout the period following the appearance of squares until August 11. The May 12 planting, however, produced nodes more rapidly throughout this period. From June 1 until August 11, a period of 71 days, the April 19 planting produced 13.1 nodes. From June 8 until August 11, a period of 64 days, the April 28 and May 5 plantings produced 11.1 and 11 nodes, respectively. From June 15 to August 11, a period of 57 days, the May 12 planting produced 13 nodes. The average number of days per node for each planting was 5.42, 5.77, 5.82, and 4.38 days, respectively.

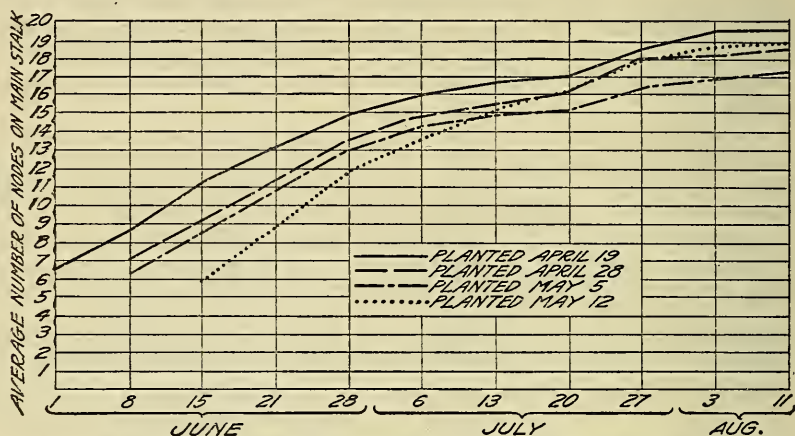


FIG. 3.—Average number of nodes on the main stalks of cotton plants at weekly intervals following the appearance of squares at San Antonio, Tex.

Each node produced on the main stalk after the beginning of the fruiting stage of the plants represents the formation of a fruiting branch. Thus, the May 12 planting produced the same number of fruiting branches in 15 days less time than was required by the April 19 planting.

Figure 4 gives the average height of 10 plants in each planting at weekly intervals from June 1 until August 11. While the height of plants is a factor of less importance than the nodal development, it will be of interest as showing the relative size of plants in each planting. The more vigorous growth of plants in the later plantings is shown in these curves. On July 13 the plants of the May 12 planting were the largest, with the May 5, April 28, and April 19 plantings following in the order named. Although the plants in the April 19 planting maintained a larger number of nodes throughout the season, after the middle of July they were the smallest. The difference in the size of representative plants in each planting is shown in Plates I and II.

This tendency toward the development of larger plants in later plantings is to be expected, especially on the heavier types of Texas

soils, when the moisture supply is plentiful. In the present experiment the late-planted cotton made considerably more vegetative growth than that planted early, in spite of drought conditions. The larger growth of the late-planted cotton resulted from the development of longer internodes on the main stalk and on the fruiting branches. Although the plants grew taller they had fewer nodes, as shown in Figure 3.

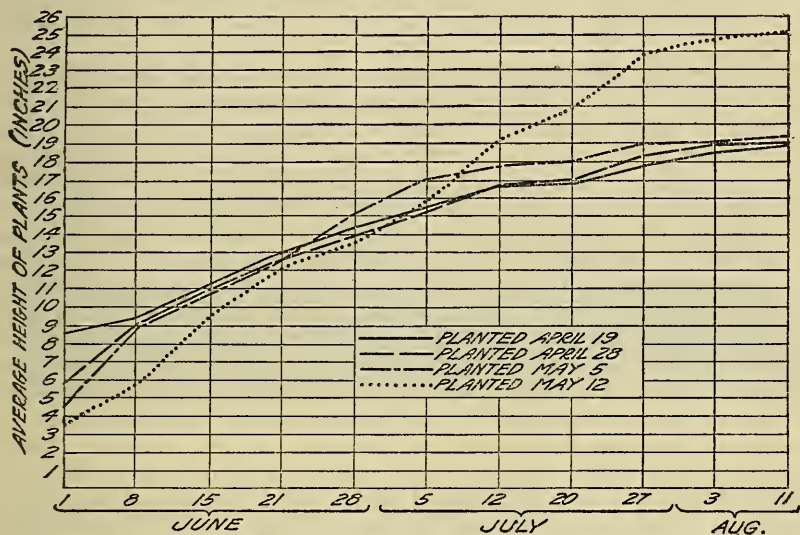


FIG. 4.—Growth in height of cotton plants at San Antonio, Tex.

PRODUCTION OF FLORAL BUDS

The fruiting capacity of a cotton plant is determined principally by the number of fruiting branches formed on the main stalk and the number of internodes formed on the fruiting branches. The plants in the successive plantings at San Antonio were small and formed few squares on secondary fruiting branches, and these are not included in comparisons of the fruiting capacity of plants.

The average number of squares formed on 10 plants in each of the four plantings is given in Table 7. The numbers of squares were recorded at 2-week intervals throughout the fruiting stage of the plants, the final record on August 11 representing the total number of squares formed on the plants.

TABLE 7.—Average number of squares recorded at 2-week intervals on cotton plants grown in successive plantings at San Antonio on four different dates

Date planted, 1923	Number of squares recorded on—					
	June 1	June 15	June 28	July 13	July 28	Aug. 11
Apr. 19.....	2.2	10.6	21.7	26.6	31.9	35.3
Apr. 23.....	0	6.5	18.6	26.4	33.3	38.7
May 5.....	0	5.7	17.6	23.1	25.8	28.5
May 12.....	0	1.7	12.8	24.2	26.4	30.9

These records show that the plants in the April 19 and April 28 plantings produced a larger number of squares than those in the plantings of May 5 and May 12. The number of squares, however, increased more rapidly on the later plantings during the first half of the squaring period, as will be seen by a comparison of the number of squares on the plants by July 13. On this date the average number of squares on plants of the May 12 planting was 24.2, as compared with 26.6 on plants of the April 19 planting, although this planting had reached the fruiting stage two weeks earlier than the planting of May 12.

The fact that the number of squares formed on the late plants by the middle of July was almost as great as the number on the early plants was largely due to a better development of the lower fruiting branches on plants of the later plantings. Table 8 gives the average number of internodes formed on fruiting branches. The numbers of internodes are determined from groups of fruiting branches, in order to simplify the presentation of the data. The first eight fruiting branches on plants of the May 5 and May 12 plantings developed more internodes than the first eight branches of the early plantings. The number of internodes on the upper fruiting branches was approximately the same on the first and last plantings, while the upper fruiting branches on the second and third plantings were not so well developed. This tendency toward the formation of more internodes on lower fruiting branches of late-planted cotton indicates that the growth of the plants was not retarded by the dry weather during June and the first part of July to so great an extent as with the early plants. This is shown in Plates I and II by the presence of squares on plants of the later plantings during the first part of August, after all squares had been shed from the plants in the early plantings.

TABLE 8.—Average number of nodes on fruiting branches of cotton plants grown in successive plantings at San Antonio on four different dates

Date planted, 1923	Branches 1 to 4	Branches 5 to 8	Branches 9 to 12	Branches 13 to 15
Apr. 19.....	1.9	2.8	2.45	1.27
Apr. 28.....	1.57	2.87	2.07	.9
May 5.....	2.17	3.07	2.07	.8
May 12.....	2.52	3.62	2.92	1.0

The average number of internodes on the first eight fruiting branches on plants of the May 12 planting was 3.04, as compared with 2.3 internodes on plants of the April 19 planting. An even more pronounced tendency toward the formation of a greater number of internodes on the lower fruiting branches of later plantings was shown in the experiments at Charleston.

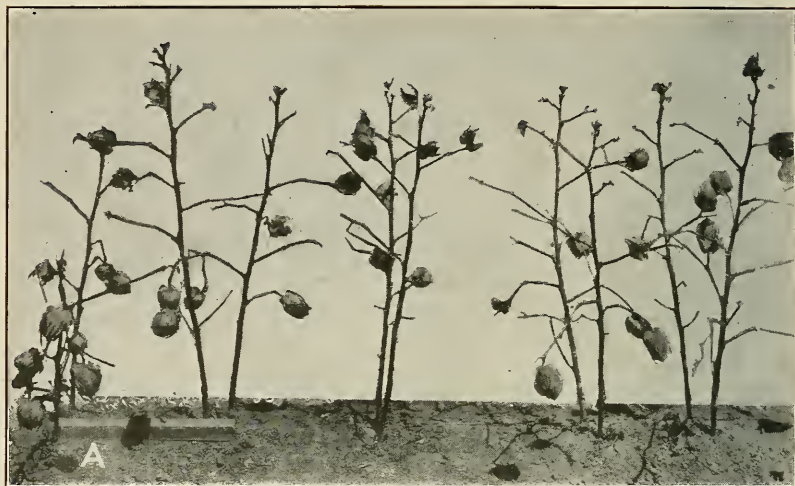
FLOWERING RECORDS OF EARLY AND LATE PLANTINGS

Flower counts were obtained from four 50-foot sections of rows in the April 19, April 28, and May 5 plantings, and from two 50-foot sections of rows in the May 12 planting. A section of row was located on the east and west ends of rows in the first and second blocks of the April 19, April 28, and May 5 plantings. No flower counts were



SIZE AND FRUITING OF COTTON PLANTS IN SUCCESSIVE PLANTINGS AT SAN ANTONIO, TEX., ON AUGUST 7.—I

A, Planted April 19; *B*, planted April 28. (Compare with Plate II)



SIZE AND FRUITING OF COTTON PLANTS IN SUCCESSIVE PLANTINGS AT SAN ANTONIO, TEX., ON AUGUST 7.—II

A, Planted May 5; B, planted May 12. (Compare with Plate I)

Note the larger size and production of vegetative branches on the plants in the May 12 planting, showing the need of closer spacing of plants in late-planted cotton. Also note the presence of squares and flowers on these plants, produced under drought conditions, which had checked growth in the early-planted cotton

made in the west end of the May 12 planting because of the very poor stand.

Flower counts were started on June 26 and were made daily until July 7. From that time until July 31 they were made every other day. The counts from each section of row in each planting are given in Table 9, with the total number of flowers counted each day in each planting shown graphically in Figure 5.

The total number of flowers counted on the west end of the rows is usually smaller than the number on the east end. This was due to retarded plant growth in the west end of the rows caused by Johnson grass in that part of the field.

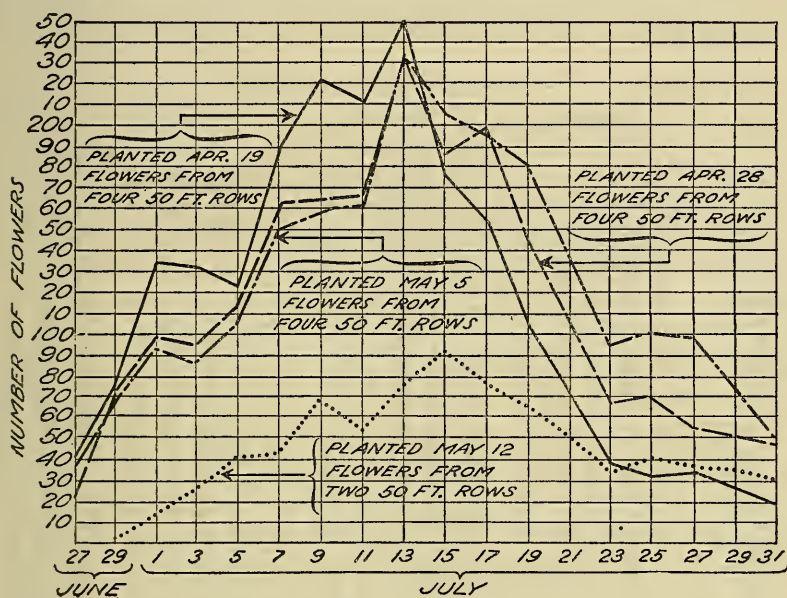


FIG. 5.—Total number of flowers recorded daily from all sections of each cotton planting at San Antonio, Tex.

The flowering of the April 19 and April 28 plantings was delayed by the removal of early squares from the plants on June 12, as previously stated. Owing to this delay, the first flowers appeared at about the same date in the plantings made on April 19, April 28, and May 5.

The plants in the April 19 and April 28 plantings were larger than those in the May 5 planting, however, and produced more flowers during the first half of the flowering period. During the period from June 26 to July 13, inclusive, the total numbers of flowers counted on the respective plantings were 1,966 on the planting of April 19, as compared with 1,635 for the planting of April 28 and 1,539 for that of May 5. Only 404 flowers were counted during the same period on the two 50-foot rows of the May 12 planting.

Although the early-planted cotton produced the largest number of flowers during the first half of the flowering period, the first three plantings reached the peak of flower production on the same day, the largest number of flowers being recorded on July 13 in each of

these plantings. During the period from July 13 to July 31, the date when flowering practically ceased, the May 5 planting produced the largest number of flowers relative to the number of plants, while the April 19 planting produced the smallest number. The total number of flowers counted during the entire season was nearly the same in each of the first three plantings, being, respectively, 2,606 for the April 19 planting, 2,517 for the April 28 planting, and 2,620 for the May 5 planting. On the two 50-foot rows of the May 12 planting 866 flowers were counted. The small number of flowers produced on these rows was due to the very irregular stand of plants.

TABLE 9.—*Numbers of flowers counted from 50-foot sections of rows of cotton grown in successive plantings at San Antonio during the period from June 26 to July 31, 1923*

Date	Planted Apr. 19					Planted Apr. 28					Planted May 5					Planted May 12		
	Block 1		Block 2		Total	Block 1		Block 2		Total	Block 1		Block 2		Total	Block 1, east	Block 2, east	Total
	West	East	West	East		West	East	West	East		West	East	West	East				
June 25	1	1	6	6	14	2	2	2	4	10	0	6	1	5	12	0	0	0
27	6	8	13	13	40	6	6	3	7	22	12	14	4	8	38	0	0	0
28	6	13	23	11	53	9	16	8	10	43	8	15	9	8	40	0	0	0
29	11	23	21	22	77	12	21	20	19	72	13	20	15	19	67	0	1	1
30	15	24	38	35	112	7	34	12	25	78	18	26	15	14	73	2	1	3
July 1	32	43	31	29	135	22	35	16	25	98	22	25	20	27	94	7	8	15
2	19	28	35	19	101	19	37	21	23	100	23	27	19	16	85	11	10	21
3	23	41	26	41	131	15	37	6	37	95	22	26	16	23	87	11	9	20
4	36	53	41	37	167	17	53	22	45	137	26	35	25	31	117	12	21	33
5	23	34	34	31	122	24	41	16	33	114	28	33	18	27	106	21	20	41
6	19	43	43	35	140	22	52	21	45	140	26	28	22	39	115	12	16	28
7	36	66	41	46	189	22	64	34	41	161	44	38	31	37	150	21	23	44
9	40	64	61	58	223	33	58	24	50	165	30	45	39	45	159	29	39	68
11	32	68	52	59	211	27	67	20	54	168	42	46	29	45	162	24	29	53
13	44	75	62	70	251	48	75	48	61	232	49	65	50	70	234	41	36	77
15	44	35	58	41	178	34	63	40	49	186	57	65	36	50	208	38	54	92
17	31	39	33	50	153	52	55	40	52	199	49	47	40	59	195	36	40	76
19	17	31	30	27	105	27	40	38	39	144	38	41	43	59	181	33	32	65
21	15	22	21	17	75	19	17	33	37	106	32	29	31	40	132	26	24	50
23	12	10	11	5	38	10	6	23	29	68	25	20	20	30	95	20	15	35
25	8	8	10	5	31	10	7	30	23	70	23	20	26	33	102	22	29	51
27	7	6	12	10	35	11	11	18	16	56	23	30	24	21	98	26	11	37
29	5	3	4	6	18	10	9	14	12	45	17	13	10	10	58	18	14	32
31	1	2	4	0	7	1	1	4	2	8	0	4	7	9	20	12	12	24
Total	483	740	710	673	2,606	459	807	513	738	2,517	627	718	550	725	2,620	422	444	866

Most of the flowers produced after the middle of July were shed as a result of adverse climatic conditions. The ability of late-planted cotton to continue flowering under severe conditions is to be noted, however. This probably was connected with the continued production of internodes on the lower fruiting branches of the late-planted cotton, which occurred both at San Antonio and at Charleston.

SHEDDING OF BOLLS IN EARLY AND LATE PLANTINGS

As a result of dry weather considerable shedding of bolls occurred in the different plantings. In order to compare the extent of boll shedding in these plantings, the numbers of shed bolls were recorded from the 50-foot sections of rows on which the flower counts were obtained. These counts do not represent the total number of bolls,

as many shed bolls undoubtedly were covered with soil when the plants were cultivated and others were shed later in the season after the records were obtained.

Table 10 gives the number of shed bolls recorded from each section of row in each planting during the period from June 30 to August 2. These bolls were picked up every day from June 30 to July 7 and at intervals of two or three days thereafter.

Boll shedding started about July 1 in the first three plantings and reached its peak on July 17. Although more bolls were shed from the April 19 planting during the period from June 30 to July 17, the larger numbers of bolls from the April 28 and May 5 plantings were shed during the latter part of July. This no doubt was due to the larger proportion of late flowers produced by these plantings.

TABLE 10.—Numbers of shed bolls recorded from 50-foot sections of rows of cotton grown in successive plantings at San Antonio during the period from June 30 to August 2, 1923

Date	Planted Apr. 19					Planted Apr. 23					Planted May 5					Planted May 12		
	Block 1		Block 2			Block 1		Block 2			Block 1		Block 2			Block 1, east	Block 2, east	Total
	West	East	West	East	Total	West	East	West	East	Total	West	East	West	East	Total	Block 1, east	Block 2, east	Total
June 30.....	0	1	4	2	7	0	0	0	1	1	0	0	0	0	0	0	0	0
July 1.....	0	3	7	1	11	0	1	1	1	3	0	0	0	1	2	4	0	0
2.....	0	7	4	5	16	1	1	1	3	6	5	6	2	4	17	0	0	0
3.....	0	3	3	1	7	1	5	0	2	8	1	6	0	3	10	0	0	0
4.....	0	3	6	8	17	2	3	3	8	16	1	5	5	5	16	0	0	0
5.....	3	3	6	3	15	1	0	13	13	26	3	7	12	9	20	1	0	1
6.....	7	7	12	9	35	1	1	9	5	16	4	4	4	9	20	1	0	1
7.....	7	7	12	9	35	1	1	9	5	16	4	4	4	9	35	4	2	6
8.....	15	24	31	27	97	13	34	16	33	96	22	30	17	18	87	12	10	22
9.....	23	61	41	35	160	21	56	17	49	143	19	46	30	33	128	23	21	49
11.....	42	76	67	61	246	44	80	48	68	240	51	51	49	36	187	26	30	56
13.....	46	106	92	65	309	49	97	44	64	254	48	46	57	56	207	33	30	63
15.....	86	129	107	96	418	71	149	55	99	374	75	108	63	86	332	32	59	91
17.....	51	117	81	96	345	67	136	39	70	312	78	106	57	83	324	45	46	91
19.....	42	73	52	90	257	52	89	55	89	285	57	78	49	75	259	40	78	118
23.....	22	33	31	26	112	29	44	35	33	141	35	40	36	54	165	28	32	60
25.....	24	12	34	17	87	36	27	45	41	149	54	39	40	68	201	57	39	96
27.....	21	24	23	24	92	25	28	32	66	151	50	60	44	74	228	50	55	105
30.....	22	33	22	28	105	24	26	22	52	124	49	55	35	63	202	33	45	78
Aug. 2.....	22	33	22	28	105	24	26	22	52	124	49	55	35	63	202	33	45	78
Total.....	412	715	617	600	2,344	446	795	428	707	2,376	561	695	503	683	2,442	390	447	837

For the period from June 30 to August 2 the total numbers of shed bolls recorded from the April 19, April 28, and May 5 plantings were 2,344, 2,376, and 2,442, respectively, while only 837 shed bolls were recorded from the two 50-foot rows of the May 12 planting. The smaller number of bolls shed from the May 12 planting is due to the fact that fewer flowers were produced.

The fact that the numbers of flowers produced and the numbers of bolls shed were nearly the same on each of the first three plantings indicates that there was no significant difference in the proportion of flowers produced and the extent of shedding during the period of observation. It is probable, however, that more boll shedding would have been recorded on the later plantings if the counts had been continued in August.

SHEDDING OF SQUARES FROM WEEVIL INJURY

As previously stated, the first indication of weevil infestation after the removal of squares and the application of poison was noted during the last week in June. The progress of the infestation is shown by records of weevil damage during the period from June 25 to July 31. These records were obtained by counting the number of weevil-punctured squares that were shed during 2-day intervals from a 50-foot section of a row in each block of each planting. These data are graphically shown in Figure 6, the total number of shed squares from the two blocks in each planting being combined in each curve.

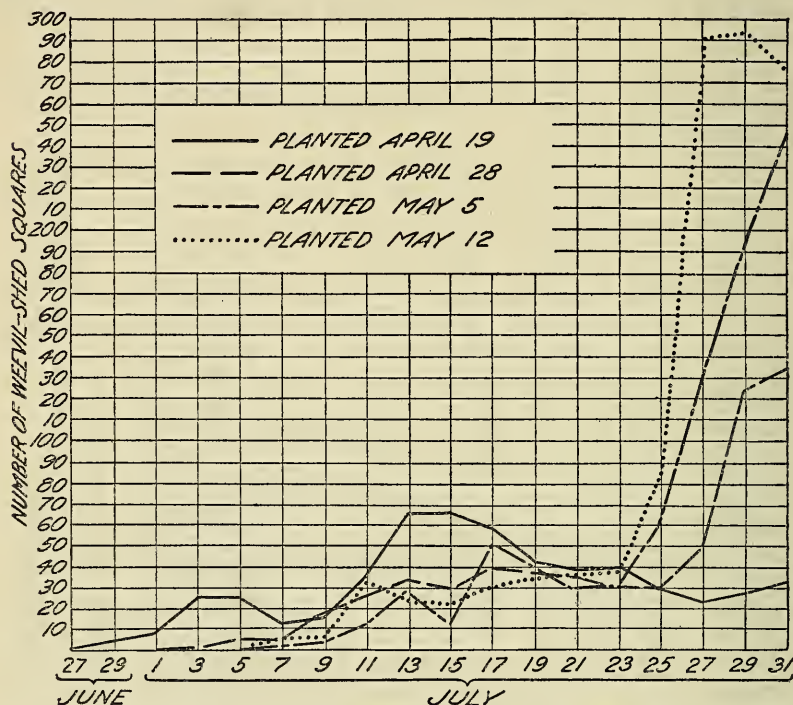


FIG. 6.—Number of weevil-shed squares from two 50-foot sections of rows in each planting of cotton at San Antonio, Tex.

The first weevil-shed squares in the April 19 planting were found on June 29 and in each of the three later plantings by July 7. The first planting showed a higher rate of square shedding during the first half of July, but the extent of weevil damage in all plantings was practically the same by the 19th of that month. The number of squares shed from the first planting decreased after this date, but increased very rapidly in each of the later plantings.

This abrupt shift in the extent of shedding is due to the fact that there were more squares on plants in the later plantings during the last half of July. It is probable that the absence of squares on the early plants resulted in a concentration of weevils on the later plantings. This condition of heavy weevil infestation in the late-planted

cotton illustrates the difficulty of obtaining accurate comparisons of productiveness from adjacent plantings of early and late planted cotton when complete weevil control is not obtained.

WEEVIL DAMAGE TO BOLLS

Records of the extent of weevil injury to bolls in the different plantings were made on four dates during the period of boll opening. These records were obtained from the same 50-foot sections of rows which were used in comparisons of flowering and boll shedding. The weevil damage was determined by counting the number of injured and uninjured locks in each of the bolls that had opened in the intervals between the four dates when the records were made. This afforded a means of comparing the extent of the injury to early and late bolls of the successive plantings.

Table 11 gives the number of bolls picked, the number showing weevil damage, the total number of locks, and the number and percentage of locks damaged by the weevils. The records from the four 50-foot sections of the first three plantings are summarized and presented in a single unit corresponding to a 200-foot row.

TABLE 11.—*Extent of weevil injury to bolls in successive plantings of cotton at San Antonio*

Date planted, 1923	Date picked	Number of bolls picked	Number of bolls damaged by weevils	Total number of locks	Locks damaged by weevils	
					Number	Per cent
Apr. 19.....	{Aug. 14	243	56	1,061	92	8.7
	{Aug. 18	312	57	1,390	89	6.4
	{Aug. 30	403	175	1,733	366	21.1
	{Sept. 10	101	72	432	163	37.7
Total.....		1,059	360	4,616	710	15.4
Apr. 28.....	{Aug. 14	161	52	719	66	9.2
	{Aug. 18	215	52	968	69	7.1
	{Aug. 30	519	249	2,258	521	23.1
	{Sept. 10	138	105	584	239	40.9
Total.....		1,033	458	4,529	895	19.8
May 5.....	{Aug. 14	105	25	472	35	7.4
	{Aug. 18	216	31	968	52	5.4
	{Aug. 30	521	313	2,387	656	27.5
	{Sept. 10	198	129	849	299	35.2
Total.....		1,040	498	4,676	1,042	22.3
May 12.....	{Aug. 30	300	192	1,410	433	30.7
	{Sept. 10	86	69	375	173	46.1
Total.....		386	261	1,785	606	33.9

The maturation period of Lone Star bolls in Texas has been shown to be about 42 days,⁴ so that bolls open before August 18 must have developed from flowers appearing prior to July 8. The small amount of weevil injury to these early bolls is due to the slight weevil infestation during the first part of the flowering stage of the plants and also to the presence of squares. While squares are available

⁴ Martin, R. D., W. W. Ballard, and D. M. Simpson. Growth of fruiting parts in cotton plants. *In* Jour. Agr. Research, v. 25, p. 204. 1923.

for the weevils to work upon, there is less injury to the bolls, though the fact that from 7 to 9 per cent of the locks on early bolls were damaged shows that the presence of squares is not a complete protection against weevil attack. The greater injury to the later bolls corresponds to the heavier infestation of weevils in the latter part of July and to the fact that there were very few squares on the plants at that time.

The increase of about 12 per cent in the injury to bolls in the planting of May 12, as compared with that of May 5, as shown in Table 11, is due to the fact that practically all the bolls produced in the last planting were from flowers appearing after July 8, so that most of the bolls in this planting were immature when the weevil infestation reached its peak during the latter part of July. It is probable also that weevil injury caused the shedding of many late bolls that otherwise might have been retained and developed to maturity.

YIELDS FROM SUCCESSIVE PLANTINGS AT SAN ANTONIO

During the first week in August the first open bolls were found on the plantings of April 19, April 28, and May 5. Although there was little difference in the time when the first open bolls appeared on these three plantings, that of April 19 matured the bulk of its crop sooner than the others. This was in accord with the larger number of early flowers produced by the first planting. The entire crop of all plantings had matured by September 10, but the scarcity of labor delayed picking until September 19.

TABLE 12.—Yield of seed cotton from successive plantings at San Antonio

Date planted, 1923	Block	Row	Number of plants			Yield of seed cotton (pounds)			
			Section A	Section B	Per row	Section A	Section B	Per row	
Apr. 19.....		1				8.25	10.00	18.25	
		2				6.75	8.00	14.75	
		3				6.25	8.12	14.37	
		4				5.44	7.25	12.69	
		{	5	198	194	392	5.87	7.87	13.74
			6	182	193	375	6.00	7.75	13.75
			7	205	198	403	4.75	7.12	11.87
			8	189	197	386	4.82	7.21	12.03
Block total.....				774	782	1,556	21.44	29.95	51.39
			9	194	185	379	5.00	6.56	11.56
	10		190	197	387	5.00	7.50	12.50	
Apr. 28.....		1	137	163	300	2.06	4.75	6.81	
		{	2	126	135	261	2.19	5.25	7.44
			3	138	147	285	3.12	6.25	9.37
			4	162	172	334	3.58	5.94	9.52
			5	131	154	285	3.31	5.64	8.95
Block total.....				557	608	1,165	12.20	23.09	35.28
		6	149	172	321	4.00	5.62	9.62	
May 5.....			1	170	187	357	3.25	5.00	8.25
	{		2	168	177	345	3.70	5.79	9.49
			3	185	186	371	3.44	4.69	8.13
			4	188	193	381	4.52	5.12	9.64
			5	195	181	376	3.87	4.18	8.05
Block total.....			736	737	1,473	15.53	19.78	35.31	
		6	170	189	359	4.00	4.12	8.12	

TABLE 12.—Yield of seed cotton from successive plantings at San Antonio—Con.

Date planted, 1923	Block	Row	Number of plants			Yield of seed cotton (pounds)		
			Section A	Section B	Per row	Section A	Section B	Per row
May 12.....		1	220	164	384	2.69	3.25	5.94
		2	63	80	143	1.00	1.12	2.12
		3	83	105	188	1.00	1.62	2.62
		4	146	135	281	2.12	2.00	4.12
		5	127	149	276	2.37	1.18	3.55
		6	72	131	203	.40	1.37	1.77
Block total.....			428	520	948	5.89	6.17	12.06
		7	107	89	196	.75	.50	1.25
		8	99	133	232	1.25	2.37	3.62
Apr. 19.....		1	186	198	384	6.50	9.06	15.56
		2	193	169	362	5.75	7.25	13.00
		3	186	184	370	5.00	6.12	11.12
		4	198	196	394	5.00	5.75	10.75
		5	198	196	394	5.50	6.94	12.44
		6	193	195	388	4.94	7.37	12.31
Block total.....			775	771	1,546	20.44	26.18	46.62
		7	490	194	384	5.67	6.73	12.40
		8	185	207	392	6.25	7.37	13.62
Apr. 28.....		1	170	174	344	3.75	4.69	8.44
		2	182	183	365	3.06	5.62	8.68
		3	160	181	341	3.50	5.00	8.50
		4	162	184	346	4.05	6.36	10.41
		5	176	144	320	4.00	3.62	7.62
Block total.....			680	692	1,372	14.61	20.60	35.21
		6	145	149	294	3.50	4.50	8.00
May 5.....		1	166	180	346	4.00	4.37	8.37
		2	177	170	347	5.25	4.37	9.62
		3	174	174	348	4.25	3.62	7.87
		4	181	173	354	4.60	5.28	9.88
		5	178	179	357	4.94	4.25	9.19
Block total.....			710	696	1,406	19.04	17.52	36.56
		6	186	168	354	5.06	3.87	8.93
May 12.....		1	173	135	308	3.25	2.37	5.62
		2	112	126	238	1.37	1.12	2.49
		3	85	113	198	.50	1.62	2.12
		4	114	142	256	2.25	.87	3.12
		5	112	162	274	2.87	2.06	4.93
		6	104	93	197	2.50	1.25	3.75
Block total.....			415	510	925	8.12	5.80	13.92
		7	100	192	292	2.25	1.75	4.00
		8	178	132	310	2.44	1.50	3.94
Apr. 19.....		1				7.19	6.81	14.00
		2				6.00	5.50	11.50
		3				6.00	6.44	12.44
		4				5.19	5.00	10.19
		5				6.25	4.75	11.00
		6				5.56	4.62	10.18
Block total.....						23.00	20.81	43.81
		7				5.75	4.25	10.00
		8				5.62	4.87	10.49
		9				7.62	4.75	12.37
		10				5.75	4.00	9.75

The rows in this test were divided into two 100-foot sections by a line stretched across the field, and the weight of seed cotton was recorded from each section of each row. Section A includes the western half of the field and section B the eastern half, where the plants were notably larger. The weight of seed cotton and the number of plants are stated in Table 12. These data are also shown graphically in Figure 7. In comparing the yields of the four plantings the weight of seed cotton from only the four inside rows of each block is used. The yields of the outside rows vary to a considerable extent, being affected by adjoining blocks of earlier or later planted cotton.

The highest yield of seed cotton was obtained from the April 19 planting, the yields from three 4-row blocks having been 51.39, 46.62, and 43.81 pounds, respectively. The yields from the April 28 and May 5 plantings were about equal. Two blocks of the April 28 planting yielded 35.28 and 35.21 pounds, while the May 5 planting produced 35.31 and 36.56 pounds. Very low yields were recorded from the May 12 planting, the two blocks having produced only 12.06 and 13.92 pounds of cotton, respectively.

Consistent differences in the yield of the east and west sections of rows occurred in all plantings. The lower yields from the west section of rows were due to the presence of Johnson grass, which retarded the growth of plants in this part of the field.

In the May 12 planting no thinning was done in parts of rows where a stand was obtained, so that the plant counts are not comparable with those obtained from the other plantings. Though the low yields of the May 12 planting may be ascribed very largely to the poor stand of plants, the larger proportion of bolls injured by the weevils was also a factor.

The higher yields obtained from the cotton planted on April 19 may also be ascribed, at least in part, to the smaller percentage of injured bolls, showing that the weevil conditions were not as severe during the early period of boll development.

Nearly the same numbers of flowers and shed bolls were recorded from the April 19, April 28, and May 5 plantings, and the totals of the yields from the four 50-foot sections of rows of each planting from which these records were obtained were nearly the same, having been 12.68 pounds from the April 19 planting, 12.15 pounds from the planting of April 28, and 11.67 pounds from that of May 5. Nevertheless, the total block yields were considerably higher on the April 19 planting.

It seems possible that the higher yields obtained from the 50-foot sections of rows in the April 28 and May 5 plantings, as compared with the total block yields, may have been due to the fact that all of the weevil-infested squares were picked up under the 50-foot sections during July for record purposes.

The additional protection that may have been given to the 50-foot sections by collecting the weevil-shed squares would not render the yields less significant. On the contrary, the yields that were secured from these sections of rows may be more indicative of the results that might have been secured if the later plantings had been apart from the earliest planting and had not been subjected to the weevil infestation from the early cotton.

PERCENTAGE OF 5-LOCK BOLLS ON EARLY AND LATE PLANTINGS AT SAN ANTONIO

A feature that was found to differ in the several plantings was the proportion of bolls with five locks. A record was obtained of the number of locks in bolls picked from four 50-foot sections of rows in the April 19, April 28, and May 5 plantings.

Data from each planting are presented in Table 13, showing the number of 4-lock and 5-lock bolls picked on August 18 and September 10 from two 50-foot rows on the east side of the field and two 50-foot rows on the west side. As stated previously, the presence of Johnson grass on the west side of the field retarded the development of the plants, and lower yields were obtained than on the east side.

The data presented in Table 13 show that a consistently higher percentage of 5-lock bolls were produced on the large plants in the east end of the rows. In the April 19 planting the large plants produced 41.2 per cent of 5-lock bolls, as compared with only 23.8 per cent on the small plants. The large and small plants in the April 28 planting produced, respectively, 49.5 and 27.6 per cent of 5-lock bolls and in the May 5 planting 50.3 and 27.6 per cent. There was little difference in the percentage of 5-lock bolls produced on the small plants in the first three plantings, but the percentage of these bolls produced on the large plants in the May 5 planting was 9 per cent higher than in the April 19 planting.

TABLE 13.—*Number of bolls and percentage of 5-lock bolls picked on August 18 and September 10 from large plants on the east end of rows and from small plants on the west end of rows in the successive adjacent plantings of cotton at San Antonio*

Date planted, 1923	Size	Date picked	Number of bolls				Per-centage of 5-lock bolls
			5-lock	4-lock	3-lock	Total	
Apr. 19.....	Small plants.....	{Aug. 18 Sept. 10	70 37	162 179	1 1	233 217	30.0 17.1
Total.....			107	341	2	450	23.8
	Large plants.....	{Aug. 18 Sept. 10	146 105	176 181	0 1	322 287	45.3 36.6
Total.....			251	357	1	609	41.2
Apr. 28.....	Small plants.....	{Aug. 18 Sept. 10	42 51	87 207	1 3	130 261	32.3 19.5
Total.....			93	294	4	391	23.8
	Large plants.....	{Aug. 18 Sept. 10	146 172	99 225	0 0	245 397	59.6 43.3
Total.....			318	324	0	642	49.5
May 5.....	Small plants.....	{Aug. 18 Sept. 10	36 87	95 225	0 3	131 315	27.5 27.6
Total.....			123	320	3	446	27.6
	Large plants.....	{Aug. 18 Sept. 10	120 178	70 224	0 1	190 403	63.2 44.2
Total.....			298	294	1	593	50.3

A SEPARATE LATE PLANTING AT SAN ANTONIO

A separate late planting of cotton was also made at San Antonio on May 12, the same date as the last of the consecutive adjacent plantings and from the same stock of seed. The surface soil had dried, but by using broad sweeps in front of the planter drill the seed was dropped in moist earth. Germination was rapid, and a fairly good stand of plants was obtained, although most of the rows had a few skips due to imperfect germination. Most of the seed in these skips germinated following a rain on May 30, but the seedlings were weak and most of them died or remained stunted. The location of this planting with relation to other fields of cotton on the experiment farm is shown in Figure 1.

CLOSE SPACING IN LATE PLANTINGS

The tendency of late-planted cotton to produce a large "rank" type of stalk under certain conditions renders it desirable to leave the plants closer together in the rows, in order to suppress excessive vegetative growth. Plants which grow large require a longer season to mature a crop, and when the season is shortened by late planting overgrown plants are an added disadvantage.

The principle of controlling the vegetative growth of plants by spacing the plants closer in the rows has been tested under a wide range of conditions. Equal or greater yields have usually been obtained from close-spaced plants when tested in direct comparison with wide-spaced plants. A greater degree of earliness is usually obtained by close spacing. In open stands with the plants averaging from 2 to 4 inches apart in the row, larger yields have been obtained without thinning.

In order to test the effect of close spacing when cotton is planted late, this experiment was planned as a comparison of plants chopped to two plants in a hill with plants left unthinned in the rows. The test consisted of three 4-row blocks of each spacing, the unthinned blocks alternating with the blocks of thinned plants. The outside blocks were protected by guard rows.

The plant spacing used in comparison with the unthinned blocks was the same as that used in the time-of-planting test, two plants being left in hills with the hills 12 inches apart. Thinning was done in these rows on June 15, when the plants averaged about 8 inches in height and had from six to eight nodes.

OVERWINTERED WEEVILS AVOIDED

Although the late-planted cotton was examined at frequent intervals for indications of weevil infestation, no trace of weevil injury was found during June.

The fact that infestation from overwintered weevils was avoided in the separate late planting probably was due to hot dry weather during the first part of June. During this period the plants were small and had not yet formed squares, so that if weevils came in they had little protection against the high temperatures and did not survive to attack the squares when they had reached sufficient size to enable the weevils to begin breeding. Thus, it appeared that the planting of May 12 had been sufficiently late to avoid infestation from overwintered weevils under the conditions encountered at San Antonio.

LATER WEEVIL INJURY

The first indication of weevil infestation in the late-planted cotton was noted on July 8, after the plants had begun to produce flowers. It is probable that this infestation resulted from migratory or stray weevils from the nearest field of early-planted cotton. A field of cotton planted on April 12 was located about 200 feet southwest of the late-planting test. This early-planted cotton was heavily infested with weevils, and migration may have occurred from this field during the first part of July.

In order to show the progress of infestation in the late-planted cotton, a record was obtained of the number of weevil-punctured squares which were shed from the plants in two 50-foot sections of rows. The number of squares shed each day are graphically presented in Figure 8. The first squares shed as a result of weevil injury were found on July 11. The shedding was very slight until July 25, when a rapid increase occurred. The sudden increase at this time



FIG. 8.—Number of weevil-punctured squares shed from a 100-foot section of row in cotton planted on April 22 and on May 12 at San Antonio, Tex. The upper line represents cotton planted on April 22; first squares on May 27. The lower line represents cotton planted on May 12; first squares on June 10. No treatment for the control of weevils was given in either field.

was probably due to an increased infestation by weevils migrating from near-by fields of early-planted cotton.

A similar record of weevil-punctured squares was obtained from a field of cotton planted on April 2, located about 600 feet north of the late-planted cotton. These data are included in Figure 8 for purposes of comparison with data regarding the late-planted cotton.

The first squares on the cotton planted April 22 appeared during the last week in May. Weevils were found on plants in this field by June 1, and a 12 per cent infestation was recorded on June 6. As squares were available early in June, it was possible for the weevils to deposit eggs and insure the appearance of a new generation of weevils by the latter part of the month. Thus, the May 12 planting did not get weevils for more than a month later than the April 22 planting, and the breeding of an early generation of weevils during June was entirely avoided in the late-planted cotton.

Even if favorable conditions for natural control of weevils did not occur, effective control might be obtained in late-planted cotton by applying poison just before squares are produced. This method of control probably would be limited to late-planted cotton which did

not produce squares until the emergence of weevils from hibernation had been completed. Poison applied before the appearance of squares in early-planted cotton would be less effective, as late emerging weevils would reinfest the field.

DEVELOPMENT OF PLANTS IN THINNED AND UNTHINNED ROWS

In order to compare the development of the plants in thinned and in unthinned cotton, records of plant height and number of nodes on the main stalk, the number of squares produced, and the number of internodes on the fruiting branches were obtained on 10 representative plants of each spacing. These records were started on June 27 and were taken at biweekly intervals until August 9.

The average number of internodes on the main stalk and the height of plants on June 27 were practically the same on plants which had been thinned to two in a hill on June 15 and on plants left unthinned. Those in both spacings averaged 11.1 nodes on this date, while the height averaged 28.8 centimeters for unthinned and 28.9 centimeters for the thinned plants.

The number of internodes on plants of both spacings remained practically equal throughout the period during which data were obtained. The final records, obtained on August 9, showed that the unthinned plants averaged 17.2 internodes, while the thinned plants averaged 18 internodes on the main stalk. The thinned plants had grown to a slightly greater size, however, their height averaging 67.3 centimeters, as compared with 63.2 centimeters on those unthinned. It is apparent that different plant spacings had a negligible effect on the development of internodes of the main stalk and on the height of the plants. The dry weather at San Antonio during this season retarded the development of all plants, and it is possible that greater differences in the size of plants would have resulted if more moisture had been available.

Although the development of the main stalk was the same on thinned and unthinned plants in this test, the thinned plants had a larger number of internodes formed on the fruiting branches, as shown by records obtained on August 9, when the growth of all plants had practically stopped. These data, showing the comparative nodal development of groups of fruiting branches on thinned and unthinned plants, are presented in Table 14. The thinned plants had a consistently larger number of internodes on each group of fruiting branches than the unthinned plants.

TABLE 14.—*Number of squares on plants and average number of internodes on fruiting branches of thinned and unthinned plants in a late-planting test of cotton at San Antonio in 1923*

Plant spacing	Total number of squares on plants at 2-week periods				Average number of internodes on fruiting branches on August 9		
	June 27	July 12	July 25	August 9	Branches 1 to 4	Branches 5 to 8	Branches 9 to 12
Unthinned	10.6	18.7	24.1	25.4	1.8	2.4	1.7
Thinned (two plants in a hill) ..	10.1	22.9	30.6	34.0	2.3	3.2	2.3

The average number of squares formed on 10 plants of each spacing is shown in Table 14. The unthinned plants averaged 10.6 squares each on June 27, as compared with 10.1 squares on thinned plants. On August 9, when the final record of all squares formed was obtained, the thinned plants averaged 34 and the unthinned plants 25.4 squares per plant.

The greater fruiting capacity of individual plants when two plants are left in hills does not represent the relative fruitfulness of thinned and unthinned cotton. When equal areas of each spacing are compared, the greater number of plants in unthinned rows, usually more than offsets the difference in fruiting capacity of individual plants. This is illustrated in Plate III by the number of bolls set on equal sections of rows of thinned and unthinned plants.

PRODUCTION OF FLOWERS ON THINNED AND ON UNTHINNED ROWS

Daily records of the number of flowers were obtained from July 2 to July 7 and at 2-day intervals thereafter until August 6. These records were obtained from a 50-foot section of rows of thinned and of unthinned plants, each section being representative of similarly spaced plants throughout the test. There were 144 plants in the section of unthinned cotton and 98 plants in the thinned section. The data of flower production are given in Table 15.

TABLE 15.—*Flowers counted in 50-foot sections of rows of cotton unthinned compared with those on plants thinned to two in a hill with the hills 12 inches apart at San Antonio*

Date, 1923	Un-thinned	Thinned	Date, 1923	Un-thinned	Thinned	Date, 1923	Un-thinned	Thinned
July 2.....	30	10	July 13.....	64	46	July 29.....	30	23
July 3.....	28	8	July 15.....	69	41	July 31.....	19	21
July 4.....	22	14	July 17.....	64	58	Aug. 2.....	4	17
July 5.....	31	11	July 19.....	54	48	Aug. 4.....	3	14
July 6.....	52	17	July 21.....	46	41	Aug. 6.....	1	11
July 7.....	33	22	July 23.....	41	35	Total.....	782	566
July 9.....	62	30	July 25.....	43	41			
July 11.....	50	17	July 27.....	36	41			

Although individual plants of thinned cotton have a greater fruiting capacity than unthinned plants, comparisons of equal areas of each spacing show that a larger number of flowers were produced by the unthinned plants. A total of 782 flowers was counted on the 50-foot section of unthinned cotton, as compared with 566 flowers on an equal section of thinned plants. The difference of 216 more flowers on the unthinned cotton represents an increase of about 38 per cent in favor of the unthinned plants in this test.

A greater degree of earliness of the unthinned plants is indicated by the number of flowers produced during the first part of the flowering period. A total of 372 flowers was recorded on the unthinned plants during the period from July 2 to July 13, as compared with 175 flowers on the thinned plants during the same period.

WEEVIL DAMAGE TO BOLLS

A record of the extent of weevil injury to bolls was obtained from two 50-foot sections of rows in the late-planted cotton. On August



PLANTS IN SEPARATE LATE PLANTINGS OF COTTON AT SAN ANTONIO,
WITH THE VEGETATIVE BRANCHES SUPPRESSED BY CLOSE SPACING

A, Two plants in a hill with the hills 12 inches apart; *B*, unthinned cotton



COMPARATIVE SIZE AND FRUITING OF COTTON PLANTS IN SUCCESSIVE
PLANTINGS AT CHARLESTON, S. C.

A, Planted April 5; B, planted April 25. (Photographed August 14)

20 all open bolls were picked, and the number of good and weevil-damaged locks was recorded. Similar data were obtained for bolls which opened between August 20 and September 1 and between September 1 and September 18.

A total of 211 bolls was picked from the two sections of rows on August 20. Of these bolls only 25 locks showed signs of weevil damage, representing 2.6 per cent of the total number of locks. On September 1, 613 bolls were picked, and 17.9 per cent of the locks were found to be damaged. Of 259 bolls picked on September 18, 34 per cent had damaged locks. A total of 18.8 per cent of the locks was damaged on the 1,083 bolls picked during the season. This weevil injury to bolls was much less than occurred in the other experiment on the cotton planted on the same date but between the earlier plantings. As shown in Table 11, the May 12 planting in the comparison of successive adjacent plantings had 33.9 per cent of all the locks damaged by weevils instead of 18 per cent in the separate late planting. This shows that even a slight isolation of the late plants had a notable effect upon weevil infestation and the resultant injury to the crop.

YIELDS FROM THINNED AND FROM UNTHINNED ROWS

The late-planted cotton was picked on September 18, at which time all bolls had opened. The field was divided into two equal sections by drawing lines across it at right angles to the rows, and the weight of seed cotton from each section of each row was recorded separately. The length of rows in each section was 100 feet.

The row yields from this test are presented graphically in Figure 7 in comparison with the row yields obtained from the successive plantings. The yields and number of plants per row in the late-planting test are given in Table 16.

The row yields of seed cotton indicate that soil conditions were very uniform throughout the field. Most of the difference in row yields resulted from imperfect stands, some of the rows having short sections with no plants or with a very irregular stand. This irregularity in stand interfered with an accurate comparison of the two systems of plant spacing, as some of the unthinned rows had fewer plants than some rows which had been thinned to two plants in a hill. The poorest stands occurred consistently on the outside rows of each block. As a 2-row planter was used it is probable that these thin stands were due to faulty operation of one side of the planter.

In view of the better stands on the two inside rows of each block, a more accurate comparison of yields may be obtained from these rows. The total yield of seed cotton from the inside rows of the three blocks of unthinned cotton was 67.07 pounds, as compared with a yield of 61.97 pounds from the inside rows of the three thinned blocks. From these weights the mean yield of one 200-foot row of unthinned cotton was found to be 11.18 ± 0.31 pounds, while the mean yield of an equal length of row of thinned cotton was 10.33 ± 0.45 pounds.

The difference in average yield of seed cotton between the unthinned rows and the rows which were thinned to two plants in a hill with hills 12 inches apart is less than twice the probable error, indicating that there was no significant difference in yield between the thinned

and the unthinned cotton. (Pl. III.) The cost of production was somewhat lower with the unthinned cotton, however, as the expense of chopping was eliminated.

TABLE 16.—*Yield of seed cotton in a late-planting test at San Antonio in 1923*

Plant spacing	Block	Row	Number of plants			Yield of seed cotton (pounds)		
			Section A	Section B	Per row	Section A	Section B	Per row
Unthinned.....	Guard..	{ 1	-----	-----	-----	-----	-----	14.00
		{ 2	-----	-----	-----	-----	-----	13.52
		{ 3	-----	-----	-----	-----	-----	10.81
Do.....	1.....	{ 4	276	282	558	6.00	4.81	10.81
		{ 5	320	347	667	6.04	5.62	11.66
		{ 6	325	321	646	5.25	5.87	11.12
		{ 6	246	177	423	5.50	4.62	10.12
Block total.....			1, 167	1, 127	2, 294	22.79	20.92	43.71
Two plants in a hill (hills 12 inches apart).....		{ 1	157	151	308	5.75	5.00	10.75
		{ 2	196	189	385	5.75	4.69	10.44
		{ 3	181	189	370	6.00	5.25	11.25
		{ 4	149	125	274	4.25	4.50	8.75
Block total.....			683	654	1, 337	21.75	19.44	41.19
Unthinned.....	3.....	{ 1	179	191	370	5.00	4.50	9.50
		{ 2	265	307	572	6.12	4.69	10.81
		{ 3	294	281	575	6.49	4.87	11.36
		{ 4	218	216	434	5.25	4.69	9.94
Block total.....			956	995	1, 951	22.86	18.75	41.61
Two plants in a hill (hills 12 inches apart).....		{ 1	143	158	301	5.50	5.50	11.00
		{ 2	194	195	389	5.20	5.15	10.35
		{ 3	196	164	360	5.50	5.19	10.69
		{ 4	155	157	312	4.62	5.00	9.62
Block total.....			688	674	1, 362	20.82	20.84	41.66
Unthinned.....	5.....	{ 1	196	169	365	4.50	4.62	9.12
		{ 2	269	256	525	5.62	5.00	10.62
		{ 3	260	271	531	6.19	5.31	11.50
		{ 4	196	202	398	5.62	5.12	10.74
Block total.....			921	898	1, 819	21.93	20.05	41.98
Two plants in a hill (hills 12 inches apart).....		{ 1	174	140	314	5.62	5.00	10.62
		{ 2	190	191	381	5.00	5.00	10.00
		{ 3	177	167	344	5.12	4.12	9.24
		{ 4	100	56	156	5.00	3.12	8.12
Block total.....			641	554	1, 195	20.74	17.24	37.98
Unthinned.....	Guard..	{ 1	-----	-----	-----	-----	-----	11.50
		{ 2	-----	-----	-----	-----	-----	12.00
		{ 3	-----	-----	-----	-----	-----	11.50

YIELDS FROM COTTON EXPERIMENTS AT SAN ANTONIO

The yields of seed cotton obtained from the separate field of late-planted cotton were greater than those from cultural and variety tests conducted at San Antonio during the same season. The yields from the late-planted cotton were exceeded only by the April 19 planting in the successive plantings. The average row yield from the late-planted test, the successive plantings, two cultural tests, and the Lone Star blocks in the variety test are given in Table 17. The same variety of seed was used in all these plantings.

TABLE 17.—Average row yields of cotton in all experiments conducted at San Antonio

Kind of experiment	Date planted, 1923	Treatment for weevils	Plant spacing	Average yield from a 200-foot row (pounds)
Separate late planting.....	May 12	None.....	Unthinned.....	11.18
	(Apr. 19)	Square stripped, poisoned.	(2 plants in a hill.....	10.33
			do.....	11.82
Successive adjacent plantings.	Apr. 28	do.....	do.....	8.81
	May 5	Poisoned.....	do.....	8.98
	May 12	do.....	Very poor stand.....	3.25
Cultural test No. 1, field C3..	Apr. 23	None.....	Unthinned.....	8.28
			1 plant to 12 inches.....	6.78
Cultural test No. 2, field C3..	do.....	do.....	1 plant to 10 inches.....	5.8
			2 plants to 10 inches.....	6.5
Lone Star check in variety test D3.	Apr. 22	do.....	6 inches.....	6.5

SOIL, CLIMATIC, AND WEEVIL CONDITIONS AT CHARLESTON, S. C.

A comparison of successive plantings of cotton was made in South Carolina on the farm of F. P. Seabrook on James Island, about 10 miles southeast of Charleston. The soil where the cotton was planted is light and sandy, well drained, and representative of the lighter type of soil of the Sea Islands. It is technically described by the Bureau of Soils as Norfolk fine sand. This type of soil normally produces a comparatively small plant and is admirably suited for cotton.

The winters are mild, and the soil becomes warm early in the spring. Cotton can usually be planted the last week in March without danger of frost injury. The summer temperatures are moderate. Rainfall is abundant and fairly well distributed, although periods of dry weather are often experienced in the spring and early summer, while periods of excessive rainfall are common in late July and August. Records of maximum and minimum temperatures and of the precipitation were obtained at James Island from March 14 to October 15. These records are summarized in Table 18.

TABLE 18.—Average maximum and minimum temperatures and monthly precipitation at James Island (near Charleston), S. C., from March to October, 1923

Items of comparison	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Average temperatures (° F.):								
Maximum.....	¹ 67.3	72.2	77.0	85.6	87.2	88.9	85.4	² 76.9
Minimum.....	¹ 51.5	54.6	65.8					
Precipitation (inches).....	2.23	1.82	6.27	2.54	9.36	8.09	3.13	3.06

¹ March 14 to 31 only.² October 1 to 15 only.

During the season of 1923 cold dry weather during April was unfavorable to the growth of cotton in the seedling stage. With warmer weather and more abundant moisture in May, growth became more rapid, and conditions were favorable for setting a crop during June and the early part of July. Excessive rainfall in the latter part of July and in August resulted in an abnormally high degree of boll shedding.

Heavy infestation from overwintered weevils is to be expected under normal conditions. The abundant protection afforded by native vegetation and the mild winters of the Sea Island sections afford excellent conditions for successful hibernation. Weevil emergence begins early, the first weevils usually being noted during April, feeding on the growing tips of the young cotton plants. The bulk of the cotton in this district is planted during the latter part of March, and squares begin to appear by the middle of May.

During 1923 many fields in this section were heavily infested with weevils by June 10, while other fields farther away from favorable hibernation places showed very slight infestation. Hot dry weather during June caused high mortality of weevil larvæ in those fields where clean cultivation was practiced and the plants were still small, so that the sunlight could reach the shed squares. Although weevil infestation was reduced by the natural control factors in June, the appearance of a new generation of weevils early in July caused infestation to increase gradually, so that in the fields where control measures were not applied infestation was practically complete by the middle of July.

COMPARISON OF SUCCESSIVE ADJACENT PLANTINGS AT CHARLESTON

Four successive plantings, as shown in Figure 9, were made on James Island on April 5, 16, 25, and May 4, each planting being in duplicate. The arrangement of the plantings was similar to those at San Antonio. Plats numbered 3, 4, 6, 7, and 8 consisted of six rows, while plats 2, 5, and 9 had seven rows, the additional row being considered as a guard, on account of being adjacent to a much earlier planting. Guard blocks 1 and 10 were also planted on each side of the field on April 5. The rows were 310 feet long and spaced 5 feet apart.

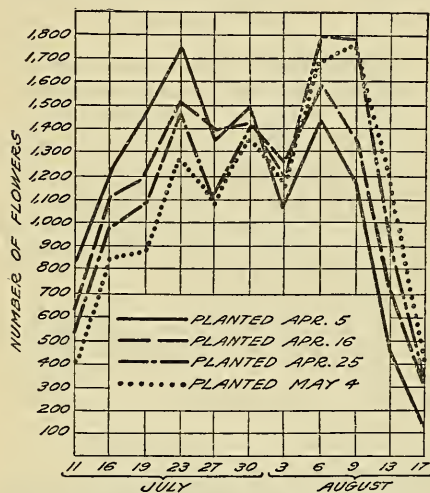


FIG. 9.—Flowering record of successive plantings of cotton on James Island, near Charleston, S. C., July 11 to August 17

The experiment was planted with seed of a very uniform strain of the Meade variety of Upland long-staple cotton.

This variety has a staple length of $1\frac{5}{8}$ inches and is adapted for use on the South Carolina Sea Islands. The

seed was planted by hand in hills 12 inches apart. The cold dry weather of April delayed germination and caused a slow growth of the early cotton during the seedling stage. With higher air temperatures and adequate moisture in May, growth became more rapid. The plants in each planting were thinned to two to the hill 12 inches apart when they reached a height

of about 6 inches. Guard plats numbered 1 and 10 were thinned to one plant per hill 12 inches apart.

DAMAGE BY OVERWINTERED WEEVILS

While cotton had been grown on an adjoining field in 1922, early destruction of stalks and unfavorable conditions for hibernation in the vicinity of the field undoubtedly afforded some protection to the 1923 planting. Although careful search was made no evidence of weevil infestation was found until June 14, when punctured squares were seen at three places in the field. Records made on June 20 showed that about 1 per cent of the squares had been damaged by weevils.

STRIPPING OF FLORAL BUDS

The entire field was stripped of squares and poison applied on June 20. The mode of procedure in the removal of squares was essentially the same as that used at San Antonio, described on pages 6 and 7. The laborers were instructed to remove all squares whose bracts were one-half inch or more long, a size that is attained in about 10 days after the young buds are large enough to be distinguished readily. There were many squares of this size or larger in the April 5 and April 16 plantings, but only a few in the April 25 and May 4 plantings that were large enough to be removed. Counts were made of the total number of squares removed from representative rows of each plat, and the average number of squares removed per plant was found to be as follows: First planting, 4.5; second 3.8; third, 1.6; fourth, 1.1. During the removal of the squares 78 weevils were captured.

Field observations indicated that reinfestation from later emerging weevils would have occurred if the squares had been removed earlier than June 20 during 1923. The planting made on April 25 was at the proper stage for stripping on June 20. Plantings made after May 1 could normally be poisoned successfully without stripping, as the weevil emergence was practically complete before the squares were large enough to harbor larvæ.

Calcium arsenate in dust form was applied to the plants on June 21 with a hand gun. Heavy rains washed the poison from the plants during the afternoon of that day. As poison should remain on the plants a minimum of 48 hours to be effective, a second application was made on June 22, which remained on the plants until June 27. No further measures were taken to control the weevil during the remainder of the season.

LATE-SEASON WEEVIL DAMAGE

Examinations were made frequently in this test for indications of weevil infestation following the removal of squares and poisoning. On July 12 two small infested spots were found, but infestation remained very slight and on July 27 was only about 3 per cent. There was no appreciable difference in the infestation of the different plantings. Migration of weevils from other fields began early in August, and by August 13 the experimental field was heavily infested. No attempt was made to control migratory weevils, as adverse weather conditions and defoliation of the plants by leafworms prevented the setting of bolls on any of the plantings after July 31.

Weevil damage to mature bolls was a minor factor as compared with damage from anthracnose, boll-rot, and bollworms.

RATE OF SEEDLING GROWTH INCREASED BY LATER PLANTING

In order to compare the rate of plant development in the four plantings, records of the formation of nodes on the main stalk were obtained from 10 representative plants in each planting. Differences in the growth rate during the seedling stage of these four plantings are shown by the interval between the planting date and the date of appearance of the first square in each planting.

As shown by the data in Table 19, the period from the date of planting to the appearance of the first square on the April 5 planting was 51 days, as compared with 44 days for the planting of April 16, 40 days for that of April 25, and 38 days for that of May 4. The latter planting reached the fruiting stage of development in 13 days less time than the planting made on April 5.

TABLE 19.—*Rate of nodal growth during the seedling stage of cotton grown in successive plantings at Charleston on four different dates*

Date planted, 1923	Average date of appearance of first fruiting branch	Number of days—	
		After planting ¹	Per node
Apr. 5.....	May 26.....	51	6.37
Apr. 16.....	May 30.....	44	5.50
Apr. 25.....	June 4.....	40	5.00
May 4.....	June 11.....	38	4.75

¹ As these records were made from the planting date rather than from the date of germination, a deduction of about five or six days is necessary in comparing these figures with those that were obtained in Texas. (See Table 3.)

The April 5 planting required an average of 6.37 days for the development of each of the first eight nodes, as compared with 4.75 days per node for the May 4 planting, a difference in growth rate of 1.62 days. Higher air temperatures and warmer soil conditions during the seedling stage of growth are probably the factors causing this increased rate of growth in the later plantings. The cotton plant is very sensitive to low temperatures, and if the young seedlings are exposed to periods of cold weather their growth may be so checked that they may not readily resume normal growth when conditions again become favorable.

PLANT GROWTH DURING THE FRUITING PERIOD

Records of plant growth during the fruiting period indicate that the accelerated development of the internodes of late-planted cotton is practically confined to the seedling stage. The average date of appearance of the first and twelfth fruiting branches on 10 plants of each planting and the average interval between the appearance of successive fruiting branches are presented in Table 20. The number of days required by each planting for the development of the first 11 fruiting branches was as follows: April 5 planting, 31 days; April 16, 27 days; April 25, 29 days; and May 4, 28 days.

TABLE 20.—*Rate of nodal growth during the fruiting stage of cotton grown in successive plantings at Charleston on four different dates*

Date planted, 1923	Average date of appearance of fruiting branches		Average number of days for production of fruiting branches		Total fruiting branches on Aug. 11
	First branch	Twelfth branch	For 11 branches	Per branch	
Apr. 5.....	May 26.....	June 26.....	31	2.82	20.3
Apr. 16.....	May 30.....	do.....	27	2.45	21.5
Apr. 25.....	June 4.....	July 3.....	29	2.63	21.2
May 4.....	June 11.....	July 9.....	28	2.54	20.5

While the rate of fruiting-branch production remained fairly constant under conditions of uninterrupted growth during June and early July, the rate of growth in the older cotton was checked about the middle of July, making it possible for the younger cotton to overcome the lead established earlier in the season by the early-planted cotton. The final measurements on all plantings, made on August 11, showed very little difference in the number of fruiting branches. The April 5 planting averaged 20.3 fruiting branches per plant, as compared with 21.5 for that of April 16, 21.2 for that of April 25, and 20.5 for that of May 4.

Each node on a fruiting branch provides for the development of a floral bud or square. Thus, the theoretical fruiting capacity of the plant may be measured by the total number of its fruiting nodes. The average per plant of the total number of squares formed on 10 plants of each planting on June 20, July 2, July 13, and August 11 are shown in Table 21. The data in this table were afforded by normal unstripped plants.

TABLE 21.—*Total number of squares per plant on given dates on cotton grown in successive plantings at Charleston on four different dates*

Date planted, 1923	June 20	July 2	July 13	Aug. 11
Apr. 5.....	22.5	41.1	52.6	66.9
Apr. 16.....	20.6	39.0	53.3	76.0
Apr. 25.....	13.6	30.4	45.6	77.4
May 4.....	8.3	26.6	42.2	82.7

On June 20 the average number of squares on the plants in each planting was as follows: April 5, 22.5; April 16, 20.6; April 25, 13.6; and May 4, 8.3, a difference of 14.2 fruiting nodes per plant between the first and fourth plantings. The greater fruiting capacity of the April 5 planting was maintained until July 13, at which time it had been passed by the second planting. Final measurements of fruiting capacity were made on August 11. While the total number of fruiting branches per plant in all plantings was practically the same on this date, the fruiting capacity of the different plantings increased progressively with later plantings. The total number of squares produced on the April 5 planting was 66.9, as compared with 82.7 on the May 4 planting. Partial cessation of the growth of the lower fruiting branches in the older plantings rather than a

slower rate of development is the cause for the complete reversal of the position of the four plantings in regard to the total number of squares formed on the plants. The later plantings continued the production of new internodes on the lower fruiting branches after the growth of the latter was checked on the older cotton. The comparative size and fruiting of early and late planted cotton are illustrated in Plate IV.

EFFECT OF REMOVING FLORAL BUDS

Records of the number of flowers produced on stripped and unstripped plants grown in Florida in 1922 indicated that an increased rate of flowering results from the removal of squares from the plants.⁵ In an endeavor to analyze the reaction of cotton plants to square stripping, comparisons of plant development and the fruiting capacity of a series of stripped and unstripped plants in each of the successive plantings were made at Charleston, S. C., during 1923. From these records it is possible to show the effect of square pruning on the height of plants, number of fruiting branches, number of internodes on the fruiting branches, and the total number of squares formed on the plants.

Squares were removed from 10 plants in each planting on June 20. Table 22 shows the average number of squares removed from these plants, varying from 10.4 squares per plant in the first to 0.8 in the last planting.

TABLE 22.—*Number of squares removed on June 20 from cotton plants grown in successive plantings at Charleston on four different dates*

Date planted, 1923	Average number of squares		
	On plant	Squares removed	
		Number	Per cent
Apr. 5.....	24.0	10.4	43.3
Apr. 16.....	21.1	8.2	38.9
Apr. 25.....	10.9	2.5	22.9
May 4.....	7.6	.8	10.5

The height of the plants was recorded weekly from June 21 until August 11. These data are presented in Table 23, showing the weekly growth in height of the stripped and unstripped plants for the four different plantings.

The plants in the first three plantings from which squares had been removed on June 20 made slightly more growth during the period from June 21 to August 11.

The increase in the growth of the stripped plants was 2.9 centimeters in the first planting, 17 centimeters in the second, and 4.7 centimeters in the third. The unstripped plants in the last, or May 4, planting made more growth than the stripped plants, the increase being 11.2 centimeters. While the comparison of growth of stripped

⁵ Smith, G. D. A preliminary report upon an improved method of controlling the boll weevil. Fla. Agr. Exp. Sta. Bul. 165, p. 18-24, illus. 1922.

and unstripped plants in the first three plantings shows that the stripped plants grew larger than those not stripped, the increases are hardly significant.

TABLE 23.—Average height of stripped and of unstripped cotton plants grown in successive plantings at Charleston on four different dates in 1923

Planting date and condition	Average height on date given (centimeters)										Growth from June 21 to Aug. 11
	June 4	June 14	June 21	June 29	July 6	July 13	July 21	July 27	Aug. 3	Aug. 11	
April 5 planting:											
Stripped.....	18.6	27.4	35.3	46.0	54.7	62.1	68.6	70.7	73.3	74.3	39.0
Unstripped.....			37.3	46.2	51.9	62.0	67.4	70.2	71.8	73.4	36.1
Increase in growth of stripped plants.....											2.9
Apr. 16 planting:											
Stripped.....	21.8	28.2	35.9	45.9	55.3	63.5	76.1	82.4	85.2	85.8	49.9
Unstripped.....			33.6	41.9	49.2	53.0	58.4	61.6	65.4	66.5	32.9
Increase in growth of stripped plants.....											17.0
Apr. 25 planting:											
Stripped.....	14.4	19.2	25.4	31.7	38.7	46.9	58.0	63.3	67.0	68.7	43.3
Unstripped.....			27.7	33.2	41.1	48.8	57.4	61.2	64.4	66.3	38.6
Increase in growth of stripped plants.....											4.7
May 4 planting:											
Stripped.....	12.0	15.8	21.3	28.2	36.7	47.2	58.9	64.1	64.0	65.4	44.1
Unstripped.....			22.8	31.5	40.8	50.6	63.9	70.8	75.8	78.1	55.3
Increase in growth of unstripped plants.....											11.2

If acceleration of fruiting results from the removal of squares this would be shown by an increase in the number of fruiting branches or by an increased number of internodes on the branches. Weekly records of the number of fruiting branches from June 3 to August 11 on stripped and on unstripped plants are shown in Table 24. In the stripped plants of the April 5 planting, from which 43.3 per cent of the squares were removed on June 20, there was a total increase of only four-tenths of a fruiting branch per plant for the entire season. The gain in the number of fruiting branches of 2.5 in the stripped plants of the April 16 planting and 0.3 in that of April 25 with a loss of 1.4 in the May 5 planting would indicate that no significant increase in the number of fruiting branches was obtained by the removal of squares. The stimulating effect of the removal of 43.3 per cent of the squares was not sufficient to change materially the normal rate of fruiting-branch production.⁶

⁶ Martin, R. D., W. W. Ballard, and D. M. Simpson. Growth of fruiting parts in cotton plants. *In* Jour. Agr. Research, v. 25, p. 195-208, illus. 1923.

TABLE 24.—Average number of fruiting branches per plant on stripped and unstripped cotton grown in successive plantings at Charleston on four different dates in 1923

Planting date and condition	Date when data were recorded											Number of fruiting branches formed from June 19 to Aug. 11	
	June 3	June 7	June 14	June 19	June 26	July 2	July 9	July 13	July 18	July 24	Aug. 3		Aug. 11
Apr. 5 planting:													
Stripped.....	4.6	6.1	8.1	10.2	13.0	15.0	16.7	17.4	19.1	19.9	21.3	21.7	11.5
Unstripped.....				9.2	11.5	13.7	15.5	16.3	17.7	18.2	19.7	20.3	11.1
Apr. 16 planting:													
Stripped.....		5.5	6.9	9.6	12.5	14.4	16.4	17.6	19.5	21.0	22.6	24.2	14.6
Unstripped.....				9.4	11.6	13.4	15.4	16.2	17.5	18.6	20.8	21.5	12.1
Apr. 25 planting:													
Stripped.....		2.6	4.5	6.4	9.0	10.7	12.9	13.9	15.4	17.3	19.6	20.3	13.9
Unstripped.....				7.6	10.0	11.6	13.6	14.8	16.8	18.2	19.9	21.2	13.6
May 4 planting:													
Stripped.....		.4	2.6	5.3	8.5	9.9	12.4	13.3	15.4	17.0	19.0	19.0	13.7
Unstripped.....				5.4	8.5	10.0	12.3	13.2	15.3	17.2	19.3	20.5	15.1

The average number of internodes per fruiting branch was obtained for the stripped and unstripped plants in each planting. For convenience, these data have been arranged in groups of five consecutive fruiting branches and are presented in Table 25.

TABLE 25.—Average number of internodes per fruiting branch of stripped and of unstripped cotton plants grown in successive plantings at Charleston on four different dates in 1923

Planting date and condition	Number of fruiting branches				Average total squares
	1 to 5	6 to 10	11 to 15	16 to 20	
Apr. 5 planting:					
Stripped.....	5.3	5.0	4.1	1.4	83.6
Unstripped.....	4.3	4.2	3.2	1.4	66.9
Increase on stripped plants.....	1.0	.8	.9	0	16.7
Apr. 16 planting:					
Stripped.....	5.7	6.2	4.8	3.1	105.9
Unstripped.....	4.2	4.8	3.8	2.1	76.0
Increase on stripped plants.....	1.5	1.4	1.0	1.0	29.9
Apr. 25 planting:					
Stripped.....	4.9	5.4	4.1	1.7	81.6
Unstripped.....	4.2	5.1	3.9	2.0	77.4
Increase on stripped plants.....	.7	.3	.2	-.3	4.2
May 4 planting:					
Stripped.....	5.6	5.6	4.2	2.0	87.0
Unstripped.....	5.4	5.3	3.8	1.8	82.7
Increase on stripped plants.....	.2	.3	.4	.2	4.3

A consistently larger number of internodes was formed on the fruiting branches of the stripped plants in the April 5 and April 16 plantings. As the total number of fruiting branches was practically the same on the stripped and on the unstripped plants the increase in number of internodes on fruiting branches resulted in a greater fruiting capacity of the stripped plants. The stripped plants in the April 5 planting averaged 83.6 squares per plant, while the unstripped

plants averaged only 66.9 squares. An even greater increase occurred in the April 16 planting, the stripped plants averaging 105.9 squares as compared with 76 on the unstripped cotton.

Only a slight increase in the number of internodes occurred on fruiting branches of stripped plants in the April 25 and May 5 plantings. As few squares were removed from these plants, no such stimulation of growth would be expected as occurred on plants from which a large percentage of squares was removed.

From the foregoing data on the effect of removal of the squares it would appear that no material increase in height or number of fruiting branches was caused. The consistent increase in the number of internodes per fruiting branch indicates, however, that the growth of the fruiting branches is affected by the removal of the early squares. A more continued or prolonged growth seems to result from their removal rather than a faster rate of development. A somewhat analogous though more extreme result of pruning is found in "boll-weevil cotton" as described by Cook.⁷

FLOWERING RECORDS OF EARLY AND LATE PLANTINGS

Flower counts were started on July 11 and were made twice a week until August 17, a period of 38 days. These counts were made on the four inside rows of two plats of the April 5 planting and on one plat of the April 16, April 25, and May 4 plantings. The length of the rows was 310 feet. The flower records for each plat are given in Table 26 and are graphically shown in Figure 9 (p. 30).

TABLE 26.—*Flowering record of cotton plants grown in successive plantings at Charleston on four different dates*

Plat	Date planted, 1923	Thinning distance	Date of counting (number of flowers)										Total of 11 counts	
			July 11	July 16	July 19	July 23	July 27	July 30	Aug. 2	Aug. 6	Aug. 9	Aug. 13		Aug. 17
No. 2..	Apr. 5	2 plants at 12 inches.	817	1,206	1,463	1,750	1,348	1,496	1,064	1,432	1,172	449	120	12,317
No. 3..	Apr. 16	-----do-----	616	1,109	1,200	1,519	1,400	1,428	1,260	1,593	1,384	714	282	12,505
No. 4..	Apr. 25	-----do-----	549	976	1,095	1,459	1,112	1,427	1,200	1,798	1,789	923	335	12,663
No. 5..	May 4	-----do-----	390	841	875	1,264	1,087	1,358	1,158	1,689	1,765	1,218	384	12,029
No. 6..	Apr. 5	-----do-----	728	1,014	1,184	1,499	1,113	1,216	1,103	1,311	1,286	593	190	11,237

Although the first flowers appeared in all plantings at nearly the same date, the more advanced development of the early-planted cotton resulted in a higher flowering rate for this planting during the first part of the flowering period. On July 11, the date on which the first counts were made, 817 flowers were counted on the first planting, as compared with 616 for the second, 549 for the third, and 390 for the fourth. A higher rate of flowering was maintained by the first planting until July 27, at which time a larger number of flowers was recorded on the second planting. Beginning on August 6, the April 25 and May 4 plantings were flowering more profusely than the two earlier plantings.

The sudden decline in the rate of flowering which occurred during the second week in August is attributable to infestation from migratory weevils and the defoliation of the plants by the cotton leafworm.

⁷ Cook, O. F. Boll-weevil cotton in Texas. U. S. Dept. Agr. Bul. 1153, 20 p., illus. 1923.

In plats 5 and 6, where the April 5 and May 4 plantings were grown side by side, 7 per cent more flowers were recorded from the May 4 planting. Owing to a high rate of boll shedding during late July and in August, few bolls were matured from flowers produced during that time.

Data were obtained from 20 plants of each of the four plantings, showing the number and percentage of bolls set from flowers which opened during weekly periods from July 7 to August 14. Data from these 80 plants are combined and presented in Table 27. During the week from July 7 to 14, 80.9 per cent of the flowers were set as bolls. Only 47.1 per cent of the flowers produced during the following week were set and 15.2 per cent during the third week. This declining rate of boll setting continued during the period from August 7 to 14, when only 3.1 per cent of the flowers set. Thus, the larger numbers of flowers produced by the later plantings during late July and August were of little value in setting a crop under the conditions of this experiment.

TABLE 27.—*Number of flowers recorded and number and percentage of bolls set on 80 cotton plants at Charleston during each of five weekly periods in 1923*

Item	July 7 to 14	July 15 to 22	July 23 to 30	July 31 to Aug. 6	Aug. 7 to 14
Flowers.....	157	276	296	205	162
Bolls:					
Number.....	127	130	45	14	5
Percentage.....	80.9	47.1	15.2	6.8	3.1

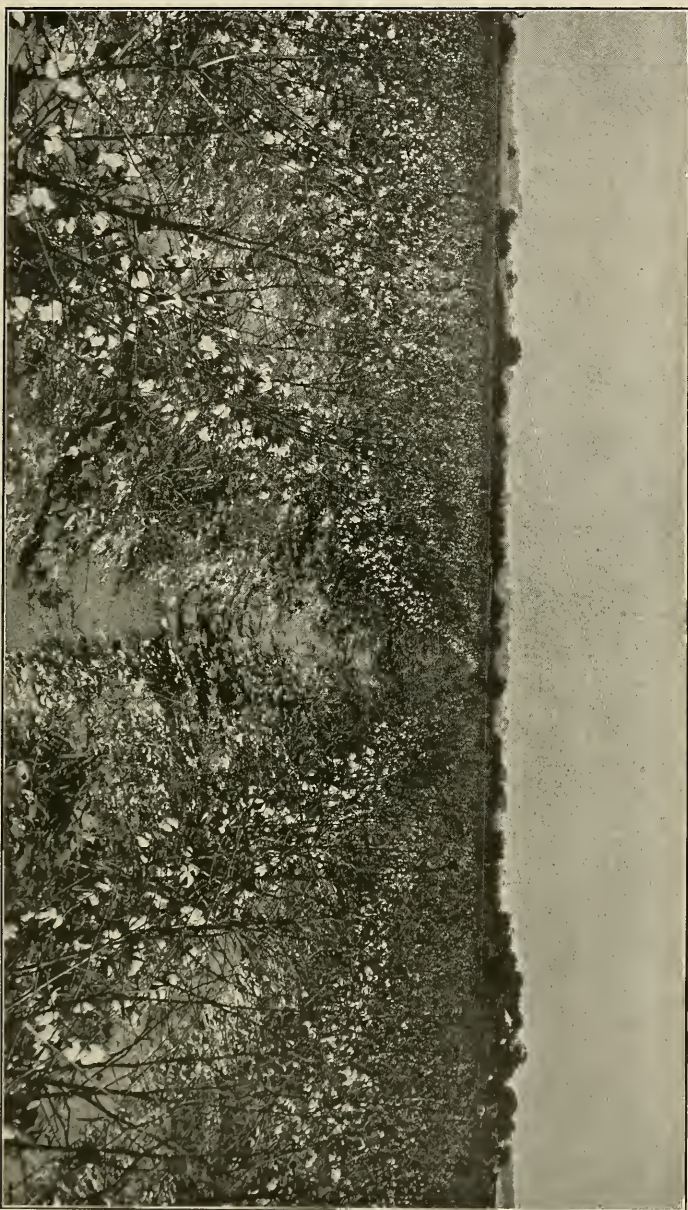
YIELDS FROM SUCCESSIVE PLANTINGS AT CHARLESTON

As a result of complete defoliation of the plants by leafworms, the bolls opened rapidly during the latter part of August, and the bulk of the crop was open the first week in September. The first picking was made on September 10 and a small second picking on October 4. The field was divided into equal sections by a line across the center of the field at right angles to the rows. Each section of each row was picked separately and weighed on scales graduated to one-tenth of a pound. The picking results are given in Table 28 and graphically presented in Figure 10.

Plant counts for each section of row are included in Table 28. Irregular stands resulted in considerable variation in the number of plants per row. While higher yields would be expected in rows having a perfect stand, it has been found impracticable to make corrections in the yields on account of deficient stands.

The yields from the four inside rows in each plat are used for comparisons between different plantings. The yields of outside rows were affected by adjoining plats of earlier or later plantings.

The total yields from the first and second plats of each planting are as follows: April 5, 279.5 pounds; April 16, 244.9 pounds; April 25, 235 pounds; May 4, 222.4 pounds. While these figures show an increase for the early-planted cotton, reference to the plat yields in Table 28 indicate that most of the gain was due to better soil on one side of the field. Plat 2, planted April 5, yielded 158.5 pounds, while plat 6, planted on the same date, yielded 121 pounds. Plats 3 and 7,



COMPARATIVE FRUITING OF EARLY-PLANTED AND LATE-PLANTED COTTON IN SUCCESSIVE PLANTINGS AT
CHARLESTON, S. C.

The April 5 planting is at the left and the May 4 planting at the right

planted April 16, yielded 136.8 and 108.1 pounds, respectively. Plats 4 and 8, planted April 25, yielded 130.6 and 104.4 pounds, and Nos. 5 and 9, planted May 4, yielded 111.8 and 110.6 pounds, respectively.

The fact that such wide differences in yield occurred on the first and second plats of the first three plantings indicates that the high yields from the first plats were due to more fertile soil in that part of the field. The yields from the first and second plats of the May 4 planting were practically equal, and comparatively small differences in the yield of the different plantings occurred on plats 5, 6, 7, 8, and 9. Plat 5, planted on May 4, yielded only 10 pounds less than plat 5, planted on April 5.⁸ (Pl. V.)

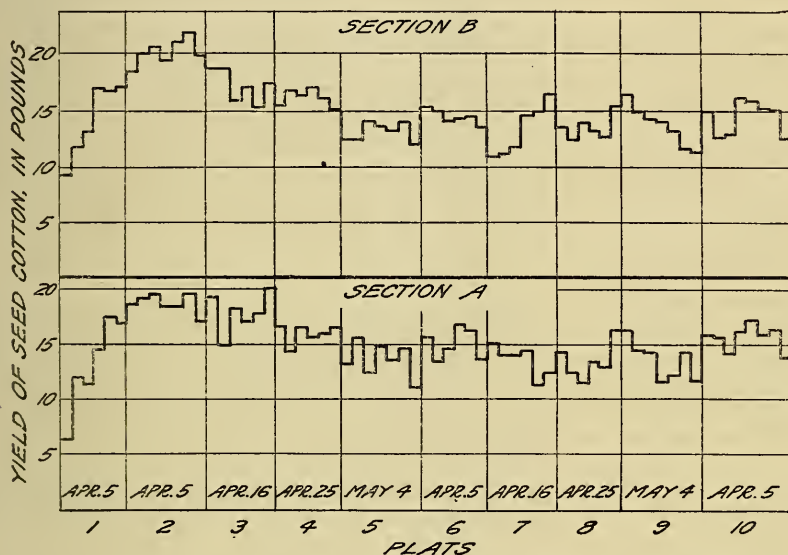


FIG. 10.—Row yields from successive plantings of cotton at Charleston, S. C., April 5 to May 4

TABLE 28.—Yield of seed cotton grown in successive plantings at Charleston on four different dates in 1923

Date planted and plat number	Row No.	Number of plants			Yields of seed cotton (pounds)						
					First picking, Sept. 10		Second picking, Oct. 4		Total		
		Section A	Section B	Total	Section A	Section B	Section A	Section B	Section A	Section B	Row
Apr. 5.....	1	214	226	440	17.1	16.1	1.7	2.5	18.8	18.6	37.4
Plat No. 2.....	2	208	207	415	17.8	18.1	1.6	2.0	19.4	20.1	39.5
	3	241	209	450	18.7	19.5	1.2	1.4	19.9	20.9	40.8
	4	242	231	473	17.2	17.4	1.4	2.1	18.6	19.5	38.1
	5	232	240	472	17.0	19.6	1.6	1.9	18.6	21.5	40.1
Total.....		923	887	1,810	70.7	74.6	5.8	7.4	75.5	82.0	157.5
	6	242	224	466	18.1	20.2	1.8	2.0	19.9	22.2	42.1
	7	139	211	347	15.6	17.6	1.7	2.4	17.3	20.0	37.3

⁸ By calculating the probable error of the average row yield of these two plats, the difference in yield was found to be only three times the probable error of the difference. As the average row yields were obtained from only eight rows, a difference of three times the probable error is not considered significant.

TABLE 28.—Yield of seed cotton grown in successive plantings at Charleston on four different dates in 1923—Continued

Date planted and plat number	Row No.	Number of plants			Yields of seed cotton (pounds)						
					First picking, Sept. 10		Second picking, Oct. 4		Total		
		Section A	Section B	Total	Section A	Section B	Section A	Section B	Section A	Section B	Row
Apr. 16.....	1	246	224	470	17.6	17.0	2.0	1.9	19.6	18.9	38.5
Plat No. 3.....	2	248	255	503	13.4	16.8	1.8	2.1	15.2	18.9	34.1
	3	232	229	461	16.3	14.1	2.1	2.0	18.4	16.1	34.5
	4	226	253	479	15.6	15.8	1.6	1.6	17.2	17.4	34.6
	5	214	217	431	16.2	14.2	1.8	1.4	18.0	15.6	33.6
Total.....		920	954	1,874	61.5	60.9	7.3	7.1	68.8	68.0	136.8
Apr. 25.....	6	243	250	493	18.6	16.3	1.8	1.5	20.4	17.8	38.2
	1	201	234	435	14.3	14.2	2.5	1.5	16.8	15.7	32.5
	2	198	242	440	12.3	14.8	2.2	2.2	14.5	17.0	31.5
	3	221	242	463	14.8	14.4	1.9	2.2	16.7	16.6	33.3
Plat No. 4.....	4	204	236	440	13.9	15.5	2.1	1.8	16.0	17.3	33.3
	5	221	235	456	14.2	14.4	2.0	1.9	16.2	16.3	32.5
Total.....		844	955	1,799	55.2	59.1	8.2	8.1	63.4	67.2	130.6
May 5.....	6	217	202	419	15.0	14.1	1.7	1.2	16.7	15.3	32.0
	1	206	189	395	12.0	11.7	1.4	.9	13.4	12.6	26.0
	2	194	152	346	13.8	10.8	2.0	1.9	15.8	12.7	28.5
	3	196	195	391	11.2	12.5	1.5	1.8	12.7	14.3	27.0
Plat No. 4.....	4	217	205	422	13.5	12.5	1.6	1.5	15.1	14.0	29.1
	5	184	173	357	11.8	11.3	1.9	2.2	13.7	13.5	27.2
Total.....		791	725	1,516	50.3	47.1	7.0	7.4	57.3	54.5	111.8
Apr. 5.....	6	224	197	421	13.6	12.7	1.4	1.7	15.0	14.4	29.4
	7	208	207	415	10.1	11.7	1.2	.6	11.3	12.3	23.6
	1	259	230	489	15.0	14.9	1.0	.6	16.0	15.5	31.5
	2	225	225	451	12.5	14.4	1.2	.9	13.7	15.3	29.0
Plat No. 6.....	3	236	244	480	13.7	13.8	1.2	.6	14.9	14.4	29.3
	4	226	242	468	16.4	13.8	.6	.7	17.0	14.5	31.5
	5	248	241	489	16.0	14.0	.5	.7	16.5	14.7	31.2
Total.....		935	953	1,888	58.6	56.0	3.5	2.9	62.1	58.9	121.0
Apr. 16.....	6	215	237	452	13.0	13.3	.9	.6	13.9	13.9	27.8
	1	262	222	484	14.5	10.5	.9	.6	15.4	11.1	26.5
	2	239	233	472	12.9	10.7	1.4	.6	14.3	11.3	25.6
	3	250	244	494	12.4	10.8	1.9	1.2	14.3	12.0	26.3
Plat No. 7.....	4	249	243	492	13.6	14.1	1.1	.8	14.7	14.9	29.6
	5	256	223	479	10.4	14.4	1.1	.7	11.5	15.1	26.6
Total.....		994	943	1,937	49.3	50.0	5.5	3.3	54.8	53.3	108.1
Apr. 25.....	6	236	232	468	12.0	16.2	.7	.5	12.7	16.7	29.4
	1	231	245	476	13.5	13.0	1.0	.9	14.5	13.9	28.4
	2	249	237	486	11.7	12.0	1.0	.7	12.7	12.7	25.4
	3	252	243	495	10.5	13.0	1.2	1.1	11.7	14.1	25.8
Plat No. 8.....	4	210	217	427	11.1	12.4	1.6	.9	13.7	13.3	27.0
	5	245	256	501	11.5	11.6	1.9	1.2	13.4	12.8	26.2
Total.....		956	953	1,909	45.8	48.0	5.7	3.9	51.5	52.9	104.4
May 4.....	6	220	256	476	15.2	14.0	1.4	1.7	16.6	15.7	32.3
	1	218	194	412	14.5	15.0	2.1	1.6	16.6	16.6	33.2
	2	203	196	399	13.1	13.7	1.6	1.3	14.7	15.0	29.7
	3	164	186	350	12.2	12.0	2.3	2.5	14.5	14.5	29.0
Plat No. 9.....	4	169	193	362	9.3	11.9	2.5	2.4	11.8	14.3	26.1
	5	149	164	313	10.1	11.3	2.3	2.1	12.4	13.4	25.8
Total.....		685	739	1,424	44.7	48.9	8.7	8.3	53.4	57.2	110.6
	6	156	125	281	11.7	10.1	2.9	1.7	14.6	11.8	26.4
	7	155	173	228	9.4	9.3	2.6	2.4	12.0	11.7	23.7

The uniformity of yields from plats 5 to 9 are shown by the graphic presentation of row yields, Figure 10.

ADVERSE CONDITIONS AT GAINESVILLE, FLA.

A series of successive plantings and a separate late planting similar to the experiments in Texas and South Carolina were also located at Gainesville, Fla., in cooperation with the Agricultural Experiment Station of the University of Florida, but owing to very adverse seasonal conditions the comparisons could not be carried out as at the other locations. The soil upon which these plantings were made is of a light sandy character with a subsoil not retentive of water. Owing to the lack of fertility in this soil cotton production is largely dependent upon the use of commercial fertilizers.

Extremely dry weather through March and April delayed germination and caused poor stands and was followed by excessive rainfall during May and June. From May 15 until July 4, a period of 51 days, rainfall was recorded on 44 days, the total precipitation being 19.37 inches. Owing to this excessive rainfall the fertilizer was leached from the soil and plant growth was greatly retarded. Even the earliest planted cotton reached a height of only 12 to 18 inches, and the growth of the late-planted cotton was so checked that many plants never reached the fruiting stage.

Weevils were present in the successive plantings before squares appeared on the plants. Squares appeared on the early plantings during the latter part of May, and on June 6 they were removed from the plants and poison was applied. The method of stripping and poisoning was the same as that used in Texas and South Carolina.

Records of weevil emergence from hibernation are maintained by the experiment station. An abnormally high percentage of hibernated weevils survived the winter of 1922-23, and emergence continued over an unusually long period. Only about 6 per cent of the weevils placed in hibernation cages normally survive the winter. On June 6, when the squares were removed from the plants in the successive planting test, 22.6 per cent of hibernated weevils had emerged. Emergence continued until July 31, at which time 26.86 per cent of the weevils placed in hibernation cages had emerged.

As a result of this prolonged period of emergence cotton became reinfested with weevils after the squares had been removed and poison applied. On July 2, however, the average infestation of squares on all cotton planted at the experiment station was only 3.24 per cent. This indicated that square removal and poisoning had been effective in delaying the appearance of the new generation of weevils, though the conditions were such that no significant data could be secured.

SUMMARY

In the season of 1923 four successive plantings of cotton were made at San Antonio, Tex., Charleston, S. C., and Gainesville, Fla., to compare the growth and fruiting habits of the plants as affected by the time of planting.

The successive plantings were treated for control of overwintered weevils by removing and destroying early squares, followed by an application of calcium arsenate. At San Antonio a separate late

planting, more remote from other cotton, was made on May 12 and was not protected by poison or square stripping.

In the successive plantings at San Antonio the squares were removed from plants of the first two plantings, and poison was applied to the entire field on June 12. Reinfestation was found two weeks afterwards, probably from weevils bred in early squares which had been shed before the control measures were used.

At Charleston the squares were removed from the plants and poison was applied on June 20. No trace of weevil injury was found until July 12.

At Gainesville the squares were removed on June 6. Abnormally late emergence of weevils caused reinfestation after control measures were applied.

Infestation from overwintered weevils was avoided in the separate late planting made on May 12 at San Antonio. This planting became infested early in July, however, probably from weevils migrating from near-by plantings.

Comparisons of plants from which the squares were stripped with unstripped plants were made at Charleston. No increase in height of plants or number of fruiting branches resulted from the removal of squares. More nodes developed on the fruiting branches of stripped plants, indicating that removal of early squares tended to prolong the period of growth of fruiting branches. (Tables 22, 23, 24, 25.)

At San Antonio and Charleston late-planted cotton grew more rapidly during the seedling stage. Nodes were produced on the main stalk at a faster rate, and the internodes were longer than on the early-planted cotton. The first squares on the later plantings were produced in fewer days after planting. (Tables 2, 3, 9.)

The last of the successive plantings at San Antonio on May 12 produced nearly as many fruiting branches as the first planting on April 19. The lower fruiting branches of the later plantings produced more nodes than the early plantings. (Tables 6, 7, 8; figs. 3 and 4.)

At Charleston the growth of the early-planted cotton was checked about the middle of July, while the later plantings continued normal growth. By August 11 the average number of fruiting branches was practically the same on all plantings. (Table 20.)

Owing to the production of more nodes on the lower fruiting branches, the later plantings produced a larger total number of floral buds than the early-planted cotton. (Table 21.)

The later planted cotton at San Antonio and Charleston continued a high rate of flowering later in the season and produced a slightly larger total number of flowers than the early-planted cotton. (Tables 9, 26; figs. 5 and 9.)

In the separate late planting on May 12 at San Antonio plants in unthinned open-stand rows when compared with plants left two in a hill showed that 38 per cent more flowers were produced in the unthinned cotton than where the plants were left in hills. More than twice as many flowers were recorded on the unthinned plants during the first 10 days of the flowering period. (Table 15.)

Data on flower production and boll shedding during the period from June 25 to August 2 indicated that the proportion of shed bolls

was practically the same on cotton planted at San Antonio on April 19, April 28, and May 5.

In the first half of July at San Antonio a larger number of squares was injured by weevils on the first planting, while during the latter part of July the number of weevil-damaged squares rapidly increased in the later planted cotton. This increase was due to the presence of many young squares on the later planted cotton, while the formation of squares on the early-planted cotton had almost ceased.

No shedding of weevil-infested squares occurred in the separate planting of May 12 at San Antonio until July 11, after flowering had started. The weevil injury to squares in this planting was much less than in the successive plantings (fig. 8).

Also there was a larger amount of injury to bolls of the later successive plantings which had a larger percentage of young bolls during the latter part of July. (Table 11.) The damage to bolls in the separate planting made on May 12 was less than occurred in the successive plantings.

The early-planted cotton yielded more than the later planted cotton in the successive plantings at San Antonio, but the last planting had a very poor stand in addition to greater weevil injury to bolls. (Table 12; fig. 7.)

The yields of the separate late planting on May 12 nearly equaled the yield of the first of the successive plantings on April 19 and exceeded the yields of the second and third plantings on April 28 and May 5. (Tables 16 and 17; fig. 7.)

The highest total yields at Charleston were produced by early-planted cotton, but with a wide variation of soil conditions in different parts of the field. Comparison of yields from a uniform part of the field showed only slight differences in the yields of the early and late plantings. (Table 28; fig. 10.)

Considering the variations that appeared in the results of the experiments and the fact that the later rows of the successive plantings were only partially protected against weevils from the earlier rows, the experiments do not show that later planting is impracticable either in Texas or South Carolina. From the nature of the problem a wide range of seasonal and soil conditions must be tested before a general advantage can be demonstrated.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

January 27, 1925

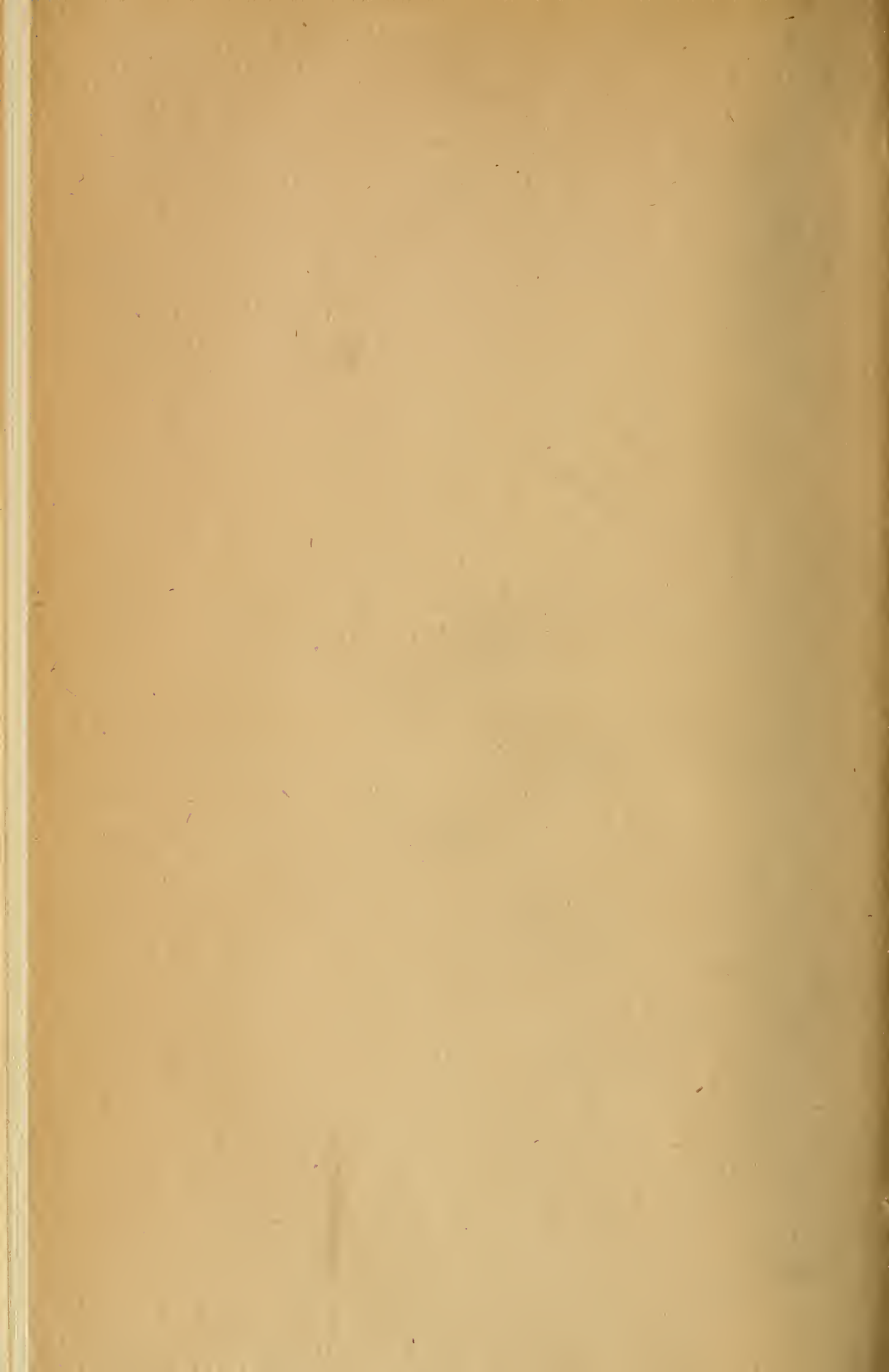
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THE OVIPOSITION RESPONSE OF INSECTS

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INTRODUCTION

Insects are generally attracted to materials for three purposes: (1) To obtain food for themselves or their progeny, (2) to lay their eggs, or (3) to gather material for their nests. In some instances the food of the adult and young is the same, and the eggs are laid directly on the substance which the adult eats. But there are many insects which show no such relation, in which the adult leads some part, often a considerable part, of its life in an environment very different from that of its immature forms. Furthermore, certain adult insects do not feed at all, yet are able, in some manner, to deposit their eggs in locations which favor the ready access of the young larvæ to their accustomed food. Indeed, there is so much precision on the part of many insects in the selection of a place to deposit eggs that students were early impressed with the idea that something directs the gravid female to, and induces her to oviposit upon, food suitable for her progeny.

It is the purpose of this bulletin to discuss the various stimuli which affect the oviposition reaction of insects. Any treatment of the subject at this time must, however, be considered preliminary. Few attempts have been made to analyze this response, although numerous observations are on record which contribute toward its

understanding. Many of these records are found in the extensive life-history literature of entomology under titles which conceal their presence. For this reason, some important contributions have probably been overlooked and, although a sincere effort has been made to cover the ground, completeness is not claimed.

The stimuli which determine when and where an insect will oviposit begin to operate far back in her life and may continue to affect her till the eggs are extruded. These influences are of two kinds, the *internal* and the *external*, and for convenience they will be taken up below in this order.

INTERNAL PHYSIOLOGICAL CONDITIONS AFFECTING OVIPOSITION

NUTRITION

There is evidence to show that the amount and character of the food of an insect affect the production of eggs. An adequate treatment of this subject would necessarily involve a discussion of nutrition and would lead beyond the limits of the present problem. It is sufficient to say here that numerous authors, including Kellogg and Bell (44),¹ Baumberger (6), Glaser (26), and Kopeć (47) have indicated that subnormal nutrition, whether due to the quantity or quality of the food, may have a decided effect on oviposition.

AGE

Among the groups of insects which possess mature eggs upon reaching the adult stage, some species, under favorable conditions, lay their eggs soon after emerging, whereas others retain them for a more or less extended period of time. The state of nutrition and weather conditions modify greatly the extent of this period (26, 40). No particular attempt has been made to assemble the literature on this subject and only two references are given here. Breit (10) states that bombycid and noctuid moths lay eggs soon after mating, while most diurnal Lepidoptera fly around a few days before ovipositing. Age has no influence upon the oviposition of *Drosophila melanogaster* Meig., provided sexual maturity has been reached (Adolph, 1).

FERTILITY

Fertility appears to be a stimulus for oviposition in some species, influencing not only the time of egg laying but also the number of eggs deposited. Normal oviposition of the cotton boll weevil (*Anthonomus grandis* Boh.) apparently will not take place till fertilization has been accomplished, but it usually begins soon after that (41). Mating accelerates the oviposition of *Heliothis obsoleta* Fab. (62). The fertile potato tuber moth (*Phthorimaea operculella* Zell.), according to Graf (29), oviposits within 24 to 48 hours after emergence and most of the eggs are laid within 4 days. The number varies from 38 to 290 eggs, the average, from 114 to 209 eggs, depending upon the nutrition of the female. Contrary to this, virgin females oviposit in from 1 to 7 days after emergence, the average time being 4.4 days. The number of eggs ranges from 1 to 51, with only 22.6 as an average. Unpublished observations of the writer on

¹ Reference is made by number (italic) in parentheses to "Literature cited," p. 13.

Ephestia kuehniella Zell. indicate that oviposition is considerably delayed and the number of eggs reduced if copulation has not taken place. Guyénot (31) and Adolph (1) obtained evidence from *Drosophila melanogaster* that mating is a stimulus for egg-laying; the former thought it was a mechanical stimulus because the first eggs deposited were frequently unfertilized. Picard (61) has also observed this effect in *Phthorimaea* and *Hesperophanes griseus* F. A recent work by Glaser (26) indicates clearly that association with the male sex stimulates egg production in *Musca domestica* L. and *Stomoxys calcitrans* L. Virgin females of the imported pine sawfly (*Diprion simile* Hartig) apparently wait 2 days before oviposition and although they can reproduce parthenogenetically, if not mated they lay only half as many eggs as fertile females (53). Mating is not a factor in the oviposition of many parasitic Hymenoptera (34, 61), nor in certain social Hymenoptera.²

INTERNAL PERIODICITIES

Adolph cites the work of Back and Pemberton (3) on the melon fly (*Bactrocera cucurbitae* Coq.) to show that internal periodicities may be responsible for the intermittent deposition of eggs by certain species. Such periodic egg-laying occurs in other insects (9) though few references to it have been found. Bishop, Dove, and Parman (8) mention that the house fly (*Musca domestica*) lays eggs at 8-day intervals.

EXTERNAL INFLUENCES AFFECTING OVIPOSITION

TEMPERATURE

Temperature influences the rate of many life processes, among which may be counted the activities connected with oviposition. Within the range of each species there is probably an optimum temperature for egg-laying. In the alfalfa weevil (*Phytonomus posticus* Fab.) mean daily oviposition follows in general the curve of mean daily temperature (57); a similar relation holds for the cotton boll weevil (*Anthonomus grandis*) (76). A reduction of 3° or 4° C. has been observed to lengthen the oviposition period of *Tomicus* (*Ips*) *typographicus* L. from 1 to 8 days (35). A cool night retards the oviposition of *Hypera punctata* Fab. and it ceases between 7° and 10° C., according to Hudson and Wood (39). A recent study by Detouches (19) on the wax moth (*Galleria mellonella* L.) shows how markedly temperature may affect the quantity of eggs laid. At 37°

² Some additional instances of fertility as a stimulus for oviposition have come to light since the above was written. According to Baker and Davidson (Jour. Agr. Research, vol. 6, pp. 351-360, 1916), the female of *Eriosoma pyricola* Baker and Davidson fails to deposit the winter egg unless fertilized directly after the last integument has been cast. *Hippodamia 13-punctata* L. will oviposit without being fertilized but scarcely one-fourth of the usual number of eggs are laid (Cutright, Ann. Ent. Soc. Amer., vol. 17, pp. 188-192, 1924). Sen (Ilept. Proc. 5th Ent. Meeting Pusa, February, 1923, pp. 215-225, Calcutta, 1924) was not able to obtain eggs from unfertilized females of *Aedes* (*Stegomyia*) *albopicta* Skuse even after the insects were allowed to bite and suck blood. Studies on *Chlorops taeniopus* Meig. by Frew (Ann. Appl. Biol., vol. 11, pp. 175-219, 1924) show that unfertilized females commence ovipositing 10 to 12 days after emergence, while fertilized females begin laying in 4 to 5 days. Unfertilized flies also lay fewer eggs than fertilized flies. Apparently the mite *Tyroglyphus mycophagus* (Mégnin) will not lay eggs unless it has been fertilized (Schulze, Zeitschr. wiss. Biol., Abt. A. Morph. und Ökologie, 2, Heft 1 and 2, pp. 1-57, 1924). It is not yet clear whether this stimulus is a mechanical one, as Guyénot has suggested, or an internal one resulting from substances transferred to the female during copulation.

C., the optimum for larval development, the female lays from 9 to 15 eggs. When intermittent temperatures of 1° and 37° are imposed for 24-hour periods throughout the life of the moth, it lives longer and lays 25 to 35 eggs. At temperatures intermediate between 20° and 37° not over 12 eggs are laid. The vital repose obtained by the lower temperature prolongs the life of the moth and an increase in egg production results. Temperature affects both the rapidity of egg-laying and the number of eggs deposited by *Phthorimaea operculella* (29). Glenn (28) states that low temperature delays egg-laying of the codling moth (*Carpocapsa pomonella*). Isely and Ackerman (42), who have recently studied the oviposition of this insect, could detect no serious check in egg-laying under optimum light conditions till a temperature of 18.3°C. was reached. Below this few eggs were laid and oviposition ceased entirely at 16.7°C. The period of highest night temperature occurs immediately after sunset, which probably accounts for the heavy oviposition at this time (Siegler and Plank, 74). Sharma and Sen (72) found that certain Indian mosquitoes preferred temperatures near 35° C. for oviposition, and high or moderately high temperatures under proper moisture conditions stimulate egg-laying in the house fly (*Musca domestica*) (Bishopp, Dove and Parman, 8). It has been shown by Roubaud (67) that *Glossina palpalis* Desv., which deposits living larvæ, is active in this respect between approximately 23° and 28° C., whereas at 30° C. reproduction is completely arrested. *Lysiphlebus tritici* Ashm. (= *Aphidius testaceipes* Cress.), a hymenopterous parasite of the green bug (*Toxoptera graminum* Rond.) attempted to oviposit, but without success, at 1.7° C., the lowest temperature at which the oviposition activity of this species was observed (27). Temperature plays an important rôle in the oviposition of *Habrobracon brevicornis* (Wesmael) (34).³

HUMIDITY

Humidity is an important factor in the egg-laying activities of many if not most insects. Shelford (73) observed that tiger-beetles require moist soil for oviposition. By increasing the atmospheric moisture from 55 per cent to 96 per cent, egg-laying of *Tomicus typographicus* was delayed from 1 to 7 days (Hennings, 35). Heavy precipitation delays oviposition in *Carpocapsa pomonella*, but whether from the effect of the moisture or from mechanical effects was not stated (Glenn, 28). High atmospheric moisture favors oviposition in the blow-flies (*Calliphora* spp., *Lucilia* spp., 81), and invariably increases the amount of egg laying in *Drosophila melanogaster* (1). It is also necessary for normal oviposition of the house fly (8, 63, 64, 68). According to Roubaud (67), the deposition of larvæ by *Glossina palpalis* ceases when the atmospheric humidity reaches the saturation point unless the fly has previously been subjected for several days to an accelerating temperature (28° C). The humidity of the usual habitat of this species is normally 90 per cent. Certain species of mosquitoes and other insects which lay their eggs upon the surface of the water probably develop a strong hydro-

³ The correct name for the species used by Hase (cf. Die Naturwissenschaft, Jahrg. 11, Heft. 39, p. 801, 1923) is *juglandis*.

tropism during the breeding season. However, the recent experiments of Sharma and Sen (72) appear to indicate that dissolved substances influence the oviposition response.⁴ According to Hase (34), the degree of moisture has no effect on the egg-laying of *Habrobracon juglandis*.

LIGHT

The character of the response of an insect to light has an important bearing on the kind of environment in which the eggs will be laid. If the response is positive, oviposition will take place in a well-lighted environment, unless, as sometimes happens, there is a reversion of the normal heliotropism during the egg-laying period. The opposite will be true of negatively heliotropic insects.⁵ Grevillius (30) states that light plays an important part in the selection of a place for oviposition by the brown-tail moth (*Euproctis chrysorrhoea* L.). An appreciable degree of darkness is essential for heavy oviposition of the codling moth (*Carpocapsa pomonella*) (42). Dewitz (21) cites a number of references which indicate that the European vine moths *Cockylis* (*Clysia*) *ambiguella* Hübn. and *Polychrosis botrana* Schiff. select the shaded grape clusters for oviposition rather than those situated in strong sunlight. According to Wardle (81), blow-flies seldom oviposit in food exposed to the sun's rays, but they lay their eggs readily in the shade. The response to light varies with the species of blow-fly concerned, *Lucilia caesar* L. being more strongly heliotropic than *Calliphora vomitoria* L. Light stimulates reproduction in the house fly (8), but is without effect on the egg-laying responses of *Drosophila melanogaster* (1).

Few observations upon the effect of color on oviposition appear to have been made. The most important of these which the writer has seen are embodied in the recent work of Knoll (46) on the relation of insects and flowers. The experiments were made on *Macroglossum stellatarum* L., a European diurnal sphingid moth which lays its eggs chiefly upon cruciferous plants of the genus *Galium*. The oviposition flight of this moth is distinct from its flight when in search of food. Knoll found that the gravid female made typical oviposition flights to reflected light from chlorophyll solutions (alcoholic solutions of crude chlorophyll and α - and β -chlorophyll from *Galium* plants); the moth reacted to the colored light and not to the odor of the solutions. A number of artificial green and yellow objects induced the oviposition flight, but in only one instance was an egg deposited. To obtain the complete response, artificial flowers made of green or yellow paper dipped in beeswax and each containing a drop of the press juice from plants of *Galium mollugo* L. were used. Gravid moths flew to these objects, exhibiting the characteristic oviposition flight and laid an egg on the under side. This result was often repeated. From these experiments, Knoll con-

⁴In a recent paper Grunb (Ent. News, vol. 35, pp. 242-243, 1924) states that certain odors arising from water are strongly attractive to gravid female mosquitoes (*Culex pipiens* L.). Experimentally, he finds dilute aqueous solutions of methane, hydrogen sulphide, old yeast infusion, and stale urine to be considerably more attractive than water alone.

⁵Thus Dietz and Zetek (U. S. Dept. Agr. Bul. 885, 55 pp., 1920) find that the eggs of the aleurodid *Aleurocanthus woglumi* Ashby are normally laid on the undersides of the leaves. The females are negatively heliotropic at the time of oviposition, for when a leaf upon which a female is ovipositing is turned over so that the light falls directly upon it, egg laying invariably ceases.

cluded that two factors were necessary to induce *Macroglossum* to oviposit, an optical factor, effective at a distance through yellow and green light and a chemical factor operating near at hand through the specific odor of the larval food plant, *Galium*. Titschack (77) found that the color of wool stuffs is not a factor in determining egg laying in the webbing clothes moth (*Tineola biselliella* Hum.).

AIR AND WATER CURRENTS

Aquatic and aerial insects are oriented in their environment by the movement of the medium surrounding them. It seems probable that ovipositing insects are also affected by stream or air movement. Wardle (81) states that wind is antagonistic to the oviposition of blow-flies. The cyrtid fly *Pterodontia flavipes* Gray deposits its eggs on the leeward side of trees (45), in which location it may be oriented by air movement.

SURFACES

In many insects, contact with an appropriate surface seems to be a necessary prerequisite for oviposition. According to Loeb (49), a highly developed stereotropism exists in the segments of the reproductive organs of animals, and further there are indications that contact with a solid affects the behavior of living matter through an influence on the rate of certain chemical reactions. Crozier and Moore (16) show that the response of diplopods to surfaces in contact with the body is essentially like the response of a positively heliotropic animal to light; that is, the animal turns its head toward the side which is in contact with a solid surface. When both sides are stimulated by contact with surfaces of equal extent, the movement of the animal is along a straight path.

In the cockroach *Periplaneta americana* L., contact with suitable material is necessary to bring about the release of the egg case (32). According to Folsom (25 p. 349), some species of grasshoppers prefer hard-baked soil for oviposition. The migratory grasshopper (*Locusta migratoria* L.) in Russia evidences a choice between different kinds of soil. Isolated females insert the ovipositor into the soil a number of times before they deposit their eggs, and often a swarm which has alighted on soil too hard for oviposition will resume flight again (80). Baillon (4) also mentions that grasshoppers choose between different types of soil for oviposition. The Mormon cricket (*Anabrus simplex* Hald.) is said to prefer a somewhat firm but not very hard soil for this purpose (13). According to McColloch (50) the corn earworm moth (*Heliothis obsoleta*) deposits more eggs on corn plants which have rough hairy stalk and leaf surfaces than on plants with smooth surfaces. The moths were also induced to lay some eggs on cotton twine. Investigations of Benedict (7) and Titschack (77) on the webbing clothes moth (*Tineola biselliella*) suggest that the tactile stimulus may be the determining factor in the selection of a place for egg laying by this species. Any rough surface was observed by Titschack to call forth oviposition, regardless of the food value of the material for the larvæ. The moths with which Benedict experimented laid their eggs on cotton and silk as well as wool, the loose threads being especially preferred. The character of the surface is apparently of

importance to the potato tuber moth (*Pthorimaca operculella*). In France, Picard (58) states that it generally lays its eggs in the cavities which surround the buds on the surface of the tuber, in incisions of the skin, or on the clumps of dried earth which adhere to the surface. It will also oviposit on the foliage of *Verbascum* and *Cynoglossum* which is felted and plaited, in preference to that of *Linaria*, for although the latter is more closely allied to the *Solanaceae* than *Cynoglossum*, its leaves have smooth surfaces. In laboratory experiments, the moths often laid a part of their eggs on the muslin sides of the cage, even when potatoes were available, but eggs were placed only exceptionally on the glass walls. Graf (29), who has studied the potato tuber moth in America, likewise reached the conclusion that oviposition was stimulated by roughened surfaces. The Angoumois grain moth (*Sitotroga cerealella* Oliv.) does not require the presence of grain as a stimulant for egg laying, but, in captivity, will readily oviposit between strips of cardboard. Usually all the eggs are deposited in the crevice between the strips (75). Dewitz (20, 22), while pointing out the possible rôle of odor in the attraction of the gravid female of *Cochylis ambiguella*, also states that oviposition on the grapevine bud may be attributed to a contact stimulation. In another paper (21 p. 233) he quotes Marchal to the effect that the female of *Polychrosis botrana* is guided during oviposition upon the smooth surface of the grape by the tactile power of the abdomen. Oviposition would not take place on grapes covered experimentally with powder or a sticky mass. The experiments of Adolph (1) on *Drosophila melanogaster* show that the texture of the substance with which the gravid female comes in contact exercises a marked effect upon the quantity of eggs laid. Boiled agar was more potent in this respect than any of the solutions which were used to test the effect of taste, odor, or a combination of taste and odor. The character of the nidus also has a very evident influence upon the oviposition of the house fly (*Musca domestica*). Under appropriate conditions, pine sawdust is considerably less attractive than timothy chaff or horse manure, and moist absorbent cotton (containing ammonium carbonate only) was oviposited upon only once in 11 experiments (63, 64). Some observations by Picard (60) on the oviposition of *Pimpla instigator* F., a hymenopterous parasite of the chrysalis of *Pieris brassicae* L., and of certain other Lepidoptera, are interesting in this connection. If an old chrysalis shell or a cylinder of white paper is coated with fresh blood from a chrysalis of *Pieris*, the parasite will pierce it with its ovipositor. The stimulus is olfactory, but according to Picard the actual deposition of the egg depends upon a tactile stimulus produced by the resistance of the living tissue within the chrysalis. Indeed, a chrysalis shell or a hollow cylinder of paper may be many times perforated by the ovipositor, but never will an egg be laid. The importance of tactile stimuli in the oviposition response of *Habrobracon juglandis* has recently been shown by Hase (Die Naturwissenschaft, Jahrg. 11, Heft 39, pp. 801-806, 1923). Touch is probably the directing sense in the oviposition behavior of *Habrocytus* (61).

In a recent publication, Howard (36, p. 36-37) declares that the stimulus for oviposition in certain chalcidoid parasites of gall-mak-

ing insects is not the morphological character of the host insect but of the gall which it inhabits. In some other parasites mentioned by this author, the stimulus seems to be furnished by the silken cocoons or webs of the host insects.

ODOROUS SUBSTANCES

A number of observations are on record which stress to a greater or less degree the importance of odor as a factor in oviposition. Scudder (71), in discussing the so-called botanical instinct of butterflies, excludes taste and sight but believes the oviposition behavior is in keeping with the idea that the larval food plant is detected by means of the olfactory sense. Trägårdh (79) places great emphasis on chemotropism, and Picard (59) also emphasizes its importance but recognizes that light, temperature, humidity, and other physical factors play a part. Brues (11) states that there is much in the behavior of certain species to suggest that food plants are selected by the female insect on the basis of odor. In addition, Brues recognizes "some attribute of the plant, perhaps an odor, but far less pronounced to our senses than odor or taste" as a factor in the attraction of insects to plants. Greavillius (30) thought it probable that the choice of a food plant on the part of the brown-tail moth (*Euproctis chrysorrhoea*) was determined by the olfactory sense. The cotton worm moth (*Alabama argillacea* Hbn.), which lays its eggs on the leaves of the cotton plant (*Gossypium* sp.), may be attracted by the nectar glands on the leaves (12). In fact, moths were seen alternately feeding from these glands and ovipositing. It was found, however, that no preference was shown for the portion near the glands on the involucre. This fact induced Comstock to question whether oviposition was here determined by the presence of the nectar glands. Studies by McCulloch (59) on *Heliothis obsoleta* show that it deposits 60 per cent of its eggs on the silks when the corn plant is in silk. Artificial silks made of cotton twine soaked in the fresh juice pressed from corn silk received 79 per cent of the eggs laid, while the controls (untreated cotton twine) received 21 per cent. Thus odor appears to be important in this case, but surfaces, according to McCulloch, must also be considered. Knoll (46) emphasizes the effect of odor upon *Macroglossum stellatarum* when the moth is close to the plant upon which the eggs are to be laid. But green or yellow light is necessary to attract the moth to the plant from a distance. The potato tuber moth is attracted by the odor of certain plants (61), but, as previously mentioned, the character of the surface is also highly important. Dewitz (20) thought the vine moth (*Cochylis ambiguella*) might be attracted and induced to lay its eggs upon or near the buds of the grapevine by the odor poured from the nectaries. But, in addition, he recognized the possible effect of contact stimulation. Loeb (49, p. 160) states that the blowfly⁶ is attracted to and will oviposit on decaying meat but not on fat. It will also deposit eggs on objects smeared over with asafetida. A positive chemotropism is responsible, according to this author, for oviposition. Fabre's observations on the blow-fly, *Calli-*

⁶ It is here called "the common house fly," but the reference is undoubtedly to one of the Calliphorae (cf. Loeb, 48).

phora vomitoria, indicate that odor is a much more important factor in oviposition than the physical character of the material on which the eggs are laid (23). A variety of substances, colored paper, oil-skin, tin foil, when placed over a receptacle which contained meat, were oviposited upon provided an opening was made in the cover. Dead birds wrapped in paper envelopes were visited by blow-flies, but they did not lay their eggs on the paper or attempt to oviposit in slits in the paper folds. Fabre attributes this behavior to a maternal foresight of the fly for an opening through which the progeny may find their way to food. His results, however, do not preclude the possibility that this behavior resulted from differences in odor concentration. The same explanation might also be offered to interpret his experiments on the larvipositing fly *Sarcophaga carnaria* L., (*op. cit.*, pp. 331-340). Wardle (81) recognizes two factors concerned in the oviposition of blow-flies, (1) the nature of the foodstuffs and (2) meteorological conditions. The stimulus for oviposition, whether olfactory or gustatory he was not sure, probably resides in the exuding juices of the food substances. Howlett (37) induced an Indian species of *Sarcophaga* to deposit larvæ in a flask which contained a solution of skatole. Subsequent experiments with skatole by Lodge (*Proc. Zool. Soc. London*, September-December, pp. 481-518, 1916), Roubaud and Veillon (68), and the writer (64) have failed to substantiate the attractiveness which Howlett claimed for this compound. He also obtained eggs of *Stomoxys calcitrans* upon cotton wool soaked in valeric acid, but an attempt to duplicate the latter result in America failed (65).

In the case of the house fly (*Musca domestica*), although the odor of ammonia from ammonium carbonate will, under suitable conditions, induce the female to oviposit (63, 64, 66), the immediate environment from which the ammonia arises also shares in determining whether egg laying will occur. If we place several pieces of solid ammonium carbonate with a little water in a glass dish, female house flies are attracted by the odor, but will not oviposit in or near the dish. A very slight response is obtained with moist cotton and ammonium carbonate which is increased when butyric or valeric acid is added. Pine sawdust is better than cotton but inferior to timothy chaff or acidulated horse manure. Wheat bran is a favorable nidus in the presence of ammonium carbonate, but eggs have not been found in fresh, moist bran which does not volatilize ammonia. It has been shown conclusively that carbon dioxide, a decomposition product of ammonium carbonate, is not in itself attractive to the gravid female house fly but, together with other factors, may exert an influence upon oviposition which has not been detected (17, 18, 66, 68). Adolph (1) found that odor is a slight stimulus to egg laying in *Drosophila melanogaster*, being most marked when flies could gain contact with the odorous solution. Texture, however, was more effective than odor, and suitable combinations of texture and odor (the flies were prevented from reaching the odorous substance) gave responses nearly equal to those which prevail under natural conditions. Townsend (78), in a study of the tachinid flies, observed that *Eupelateria magnicornis* Zett., which deposits living larvæ on the foliage of plants, seeks for this purpose only those portions over which the host caterpillars have crawled. The parasitic

larvæ are usually placed on stems where a silken thread has been left by a caterpillar, and Townsend suggests that the sense of smell induces the flies to larviposit in such locations. Picard (60) states that the functioning of the ovipositor of *Pimpla instigator* is a reflex determined by an olfactory sensation, but that the tactile sense governs the actual deposition of the egg in the host. The investigations of Hase show that odor is all important in the discovery of the host by *Habrobracon juglandis* but that tactile stimuli are necessary to bring about the deposition of the egg (34; cf. also Die Naturwissenschaft, Jahrg. 11, Heft 39, p. 801, 1923).

CONTACT WITH CHEMICAL SUBSTANCES

In addition to the effects produced by the purely physical character of surfaces there yet remains the possibility that the oviposition behavior may be influenced by direct contact of the insect's body with chemical substances. Responses due to the sense of taste and to the general chemical sense probably belong here. McIndoo (51, 52) believes that the senses of smell and taste in insects are inseparable. Minnich (54, 55, 56), however, has recently described a chemical sense analogous to taste located on the tarsi of two species of Lepidoptera, *Pyrameis atalanta* L. and *Vanessa antiopa* L. Experiments on *Drosophila melanogaster* (1) indicate that the taste of an aqueous glucose solution is much more effective in evoking oviposition than the odor of a solution which contains a mixture of acetic acid and alcohol, although the latter mixture has a marked food attraction for this fly (5). Sharma and Sen (72), in a study of the oviposition of mosquitoes, find that weak solutions of sodium chloride, sodium citrate, sodium tartrate, and certain other salts are conducive to egg laying, while the corresponding acids are repellent. Observations of Hancock (33) on the oviposition of the grasshopper *Orchelimum glaberrimum* Burm. reveal the interesting fact that this insect, when searching for a place to lay its eggs, either ignores the plants distasteful to it or subjects them to a brief mouth test (cf. 4, p. 134). Although not proving the point, these observations suggest that taste plays a part in the selection of the plant. Brues (11) places taste among the senses which direct gravid female insects to plants.

DISCUSSION

Insects which spend most of their lives upon substances that offer food for themselves or their offspring probably exhibit the simplest oviposition responses. When the internal physiological conditions are right, simple contact with the stimulating medium appears to be all that is necessary to release the eggs. The behavior of the ovipositing queen bee suggests that the response is largely determined by the tactile sense and this may also be true of other colonial insects. The webbing clothes moth (*Tineola biselliella*), which oviposits as readily upon the surfaces of indigestible materials as upon the natural food of its larva, likewise seems to lay its eggs largely in response to tactile stimuli.

Contrasted with these simpler cases, the oviposition response of many active free-living species is much more complex. The inten-

sity and wave length of light, temperature, and humidity, rate of movement of the medium in which she lives, odor, and the physical and chemical character of surfaces aid in bringing the gravid female insect into contact with the specific larval food and induce her to release the eggs. A given set of stimuli is not effective for all species. Thus, for *Drosophila melanogaster* the stimuli may be roughly classified in the following ascending order of effectiveness: Odor, moisture, taste, odor and taste, texture, texture and odor, and a combination of texture, taste, and odor. In comparison with *Drosophila*, the house fly is more dependent on the odor of the medium; most substances which do not liberate ammonia probably seldom, in nature, evoke egg deposition. The response of *Macroglossum* to green and yellow light presents a reaction at present apparently unique among insects, but which further study may show to be widespread in those species which lay their eggs on green plants.

The experimental evidence at hand suggests, then, that a chain of stimuli is, in many species, necessary to induce egg deposition. Adolph (1, p. 338) sets forth this view in the following words:

Egg laying in its nature is a complete response ("all or none"); that is, partial stimulation can not be measured. A single potent factor in the chain may never lead to the extrusion of eggs.

A similar view is gained by Knoll (46, p. 349) from his study of *Macroglossum*, by Picard (60) from observations on *Pimpla instigator* F., by Hase from studies on *Habrobracon juglandis*, and the results of the writer's experiments on the house fly are concordant with it.

Loeb (49) seems to favor the idea than an odor stimulus is sufficient to produce oviposition in certain free-living insects. He says (p. 160):

The fact that eggs are laid by many insects on material which serves as a nutritive medium for the offspring is a typical instinct. An experimental analysis shows again that the underlying mechanism of the instinct is a positive chemotropism of the mother insect for the type of substance serving her as food; and when the intensity of these volatile substances is very high, that is, when the insect is on the material, the egg-laying mechanism of the fly is automatically set in motion. Thus the common house fly [see footnote, p. 8] will deposit its eggs on decaying meat, but not on fat; but it will also deposit it [them] on objects smeared over with asafetida on which the larvæ can not live. * * * It seems that the female insect lays her eggs on material for which she is positively chemotropic, and this is generally material which she also eats.

Fabre's observations on the blow-fly *Calliphora vomitoria* emphasize the predominance of odor in this response, and Howlett's results with *Sarcophaga* would appear to leave little doubt that odor alone can induce insects to oviposit. It must be said, however, that Howlett's experiments are given in little detail and might be accidental or unusual rather than the customary response of the fly in question. And the observations of Loeb and Fabre do not exclude effects due to the surface with which the flies came in contact. At all events, it is desirable that thoroughgoing evidence be obtained before accepting as fact the proposition that free-living Diptera can be induced to lay eggs solely by means of an odor stimulus. It seems necessary to stress the dependence of chemotropism upon other factors at this point because certain entomologists have rather accepted

it as the stimulus responsible for the oviposition of insects. From present knowledge, however, it seems doubtful whether a free-living insect can ever be induced to oviposit by means of an odor stimulus alone.

The reaction of *Drosophila* to odor concentration is interesting. It has been shown by Adolph (1, p. 334, 335) that odor concentrations are never so low that they fail to call forth positive responses, and even very faint odors have full stimulating value. If this proves true of many insects it will perhaps explain how the faint odors emanating from the green portions of some plants may possess great stimulating value, particularly when the insect is near by.

In captivity, some species will oviposit on almost any convenient surface, but others hold strictly to specific substances and refuse to oviposit in their absence. Among Lepidoptera, for example, there are species (*Satyrus dryas*, *Carpocapsa pomonella*) which lay their eggs at random on the walls or floor of the cage, and others which refuse any but a particular food plant for this purpose (*Papilio machaon* L., *Pieris brassicae*, *Arginnis selene* Schiff., and others, 24, 43, 69). These results show the difference in oviposition behavior that may occur in the same family of insects.

It has been observed, however, that there are occasional errors of judgment on the part of female insects which have specialized food plants; that eggs are, in fact, sometimes placed upon plants which can not nourish the larvæ. Knoll (46) observed the habits of *Macroglossum stellatarum* in captivity, the larva of which is closely restricted to plants of the genus *Galium*. After retaining the eggs a long time, the female will deposit them on any available green portion of a plant, regardless of its botanical relationships. And more recently Schwarz (70) concludes from observations on *Catocala* extending over a number of years that such mistakes in oviposition are a phenomenon of old age and a sign of physical exhaustion.

The question now arises, how has the female insect obtained the ability to respond to these stimuli which lead it almost unerringly to the specific larval food? Is it impelled by a series of tropisms, or by an instinct which is the result of natural selection, or by an acquired instinct now hereditarily fixed? The tropistic view has been advanced by Loeb (48, 49), Trägårdh (79), Howlett (37, 38), and others. Brues (11) and Loeb (49, p. 160) have mentioned the possible relation of natural selection to food selection by the female insect. Bachmetjew (2) believes that the female insect must have an acquaintance with the taste of the larval food plant which it has inherited from the larva. To use his own words (p. 713).

Allein der Geruchsempfindung bei der Wahl der betreffenden Pflanzengattung die Geschmacksempfindung geschichtlich voran, denn um zu wissen, wo er seine Eier ablegen soll, musste der Falter zuerst mit dem Geschmack der betreffenden Pflanze bekannt gewesen sein, resp. dies von der Raupe geerbt haben.

Wheeler (82, p. 71-72) states that oviposition and feeding upon the host blood in the parasitic Hymenoptera are congenitally or hereditarily conditioned reflexes. Little of an exact nature seems to have been done to elucidate this important question. However, the very suggestive experimental investigation of Craighead (14, 15)

throws considerable light upon it.⁷ Craighead finds that nearly all adult cerambycids display a marked preference for the host wood in which they have fed as larvæ, and that certain species which can be induced to feed in a new host show a preference for that host when they become adults. Concerning oviposition, he says (14, p. 220):

Although the adults show a decided predilection for a favored host in ovipositing and even, in certain species, a preference for the plants in which the larvæ have fed for one or two generations, the instinct to oviposit seems to overbalance that of host selection, consequently new hosts are frequently selected—possibly more frequently in nature than is generally realized.

If it can be shown that the food of the larva determines the host preference of the adult, a decided step in advance will have been made. Another step then will be to explain whether the "memory" of the food plant which the larva has passed on to the adult is the result of or is influenced by the chemical or physical effects of the food in the growing larva.

CONCLUSIONS

The following internal factors may condition the oviposition responses of insects: The nutritive state as affected by the amount and chemical constitution of the food, age, fertility, and internal stimuli which determine periodic egg-laying.

The external influences which may affect the oviposition response are temperature, humidity, light (including color), air currents (and probably in some species water currents), the physical character of surfaces, the chemical constitution of substances which stimulate on contact, and the volatile constituents of substances.

The simplest oviposition responses are probably shown by insects which spend most of their lives upon substances that serve as food for themselves and their offspring.

Most free-living insects, however, require a chain of stimuli to provoke egg laying; a single stimulus is insufficient to call forth a normal response. Many species demand a specific chain of stimuli.

The odor of a substance may attract gravid female insects, but is probably never in itself sufficient to induce normal oviposition.

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UNITED STATES DEPARTMENT OF AGRICULTURE



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THE FLIGHT ACTIVITIES OF THE HONEYBEE¹

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INTRODUCTION

Although the flight of honeybees to and from the hive has attracted the attention of students of beekeeping from the earliest times, no detailed study has been made, so far as can be determined from the beekeeping literature, of the actual number of flights from a colony of bees or of the variations which occur in these flights with changes in external environmental factors. Obviously it is extremely difficult to obtain even a small number of accurate records by counts made at the entrance of the hive. Therefore, to obtain adequate scientific data for a thorough study of the problems pertaining to the flight of bees it is essential to have some mechanical means which will automatically register the exits and returns of the bees over long periods of time.

¹ This paper was prepared in part fulfillment of the requirements for the degree of doctor of philosophy at Cornell University. While engaged in this work the author held a Government overseas scholarship from the Department of Agriculture of the Union of South Africa. The work was done in cooperation with the Bee Culture Laboratory of the Bureau of Entomology, at Somerset, Md. The writer is indebted to the Carnegie Fund of the Imperial Bureau of Entomology, London, and to the Department of Agriculture, Union of South Africa, for financial assistance. He was regularly assisted in the taking of data by Miss Effie Ross and from time to time by other members of the Bee Culture staff. He also gladly acknowledges his indebtedness to Prof. F. Y. Edgeworth, All Souls College, Oxford, several of whose published articles have been found of value, and to Prof. H. H. Love, Cornell University, and Dr. G. W. Vinal, Bureau of Standards, for helpful suggestions.

While reading an interesting paper by Léon Dufour,² in which are shown the great variations which the weight of a hive undergoes in the course of a single day, the writer, seeing how the incoming nectar and pollen modified the interpretations of the flights which occurred, realized more fully the scientific value of an automatic apparatus which would register the exits and returns of the individual bees, and was led to spend the greater part of the winter of 1921-22 in devising an apparatus for this purpose.

Actual recording of individual flights was begun on April 8, 1922, with 14 units of the apparatus in place. On May 10 the full quota of 30 instruments was installed and readings were continued regularly, including Sundays and holidays, from daylight to dark, until July 29, except for six days, when the work was interrupted by certain necessary modifications or adjustments of the apparatus. During this period some five million flights to and from the hive were recorded, the gross weight of the bees representing half a ton.

Since the first object of this experiment was to determine the practicability of obtaining data on problems pertaining to the flight of bees by means of an automatic recording mechanism, rather than to make a study of any one of these problems, and since there appears to be no immediate opportunity for the writer to continue this interesting line of investigation, it seems best to record the data so far obtained, that they may serve as at least an introduction to a further study of this phase of bee behavior.

THE APPARATUS

At the outset it was clear that, on account of the limited space at the hive entrance, the most practical apparatus for counting the flights of bees would be one in which each bee would establish electrical contact as it left or as it entered the hive. Any such apparatus must consist of as many units as will accommodate the full flight of the colony under experimentation, each unit consisting of one contact device and one recording mechanism.

THE CONTACT DEVICE

A device for establishing electrical contacts that will give the desired data is one which requires for its operation little or no exertion on the part of the bee and which will delay the bee very little or not at all in its departure or return. To meet these requirements there are at least three possible methods of approach, arranged here in the ascending order of their complexity and expense.

- (1) To allow the bee to push against some mechanism.
- (2) To allow the weight of the bee to operate some mechanism.
- (3) To use a minute electric current, the circuit of which is closed by the body of the bee itself as it passes the terminals, but not strong enough to cause any modification of behavior, and then to amplify this current so as to operate the recording mechanism.

Working on the plan of allowing the bee to push against some mechanism, a modification of the ordinary bee-escape which allows bees to pass but one way was tried. A small wire was soldered at

² Dufour, Léon. Travail des butineuses et récolte du miel. In *L'Apiculteur*, vol. 41, no. 8, pp. 300-312. 1897.

right angles to one of the springs, so that as the bee passed between the springs this wire was pushed into a small cup of mercury, thus closing the electric circuit. It is a simple enough matter to get a bee to form such a contact, but to get each contact to represent the passage of but one bee proved to be exceedingly difficult and is perhaps impossible. Seven different devices of this sort were constructed and tested, each intended to overcome some defect inherent in those preceding. Regarding these devices, it suffices to say that none of them proved practical. One of the chief difficulties was the fact that the springs may be so delicately adjusted that on the passage of a bee a contact may be formed by the head and thorax and then another contact formed by the abdomen. Yet another bee passing these same springs in a slightly different manner may get through without forming any electrical contact whatever. An attempt was made to overcome this difficulty by taking advantage of the smaller constriction which exists between the dorsal surface of the propodeum and the abdomen; that is to say, the bee was forced to walk in an upright posture, through a tube of special cross section, so that the spring passed over this dorsal region. The bees, however, showed great reluctance to go through such a tube.

George S. Demuth and N. E. McIndoo, both formerly connected with the Bee Culture Laboratory, have informed the writer that they, too, have given some thought to this problem. Mr. Demuth attempted to get the bees to push against prongs placed equidistant around a revolving wheel, much on the principle of the undershot water wheel. Doctor McIndoo tried to get the bees to push against small hinged gates. Neither attempt was carried to completion.

Owing to the fact that the stimulations of bees to flight, such as light intensity, nectar flows, and other environmental factors, vary greatly in degree, and also that individual bees apparently differ somewhat in their reactions to even slight obstacles placed in their way, it is questionable whether any apparatus working on the principle of having the bees push against a mechanism will ever be found practical.

Attention was then turned to the possibility of utilizing the weight of the bee to form an electrical contact. Three models were constructed on this plan, each proving to be a step in advance. The third model, after several long tests, appeared to be the instrument required. After a few minor improvements in the design, 30 such instruments were built, 15 to accommodate outgoing bees and 15 for incoming. These instruments are referred to in this paper as "gates."

This device (fig. 1) may be described as a miniature balance on jeweled pivots. As the bee enters the tunnel fixed to one end of the lever, its weight, having a greater moment than the counterbalance, causes the tunnel to drop and this movement produces three consecutive results: (1) It closes the door to prevent a second bee from gaining entrance to the case while the tunnel is on its downward stroke; (2) it establishes an electric contact by thrusting two platinum prongs attached to but insulated from the lever, into two mercury cups; and (3) it opens a second door on a lower level, permitting the bee to fly to the field or to enter the hive, as the case may

be. The bee having left the tunnel, the counterbalance now has a greater moment than the empty tunnel, the second door is closed, contact is broken, and the first door is opened, so that the mechanism is now ready to count the next bee. This seesaw motion continues as long as bees are passing through the tunnel. The illustration (fig. 1) shows an incoming gate. The only difference between this and an outgoing gate is the presence of glass immediately in front of the tunnel on the outgoing gate, and a different position of the binding posts. The tunnels adopted after some experimentation were 15 millimeters long, from 6.5 to 7 millimeters wide, with a curved upper portion from 4.5 to 5 millimeters at the highest point. These were so adjusted that a 67-milligram weight placed at the base of the rear door brought the tunnel down to the lower stop. At other times 75-milligram and 47-milligram weights were used, but most of the data were obtained with the first-mentioned adjustment.

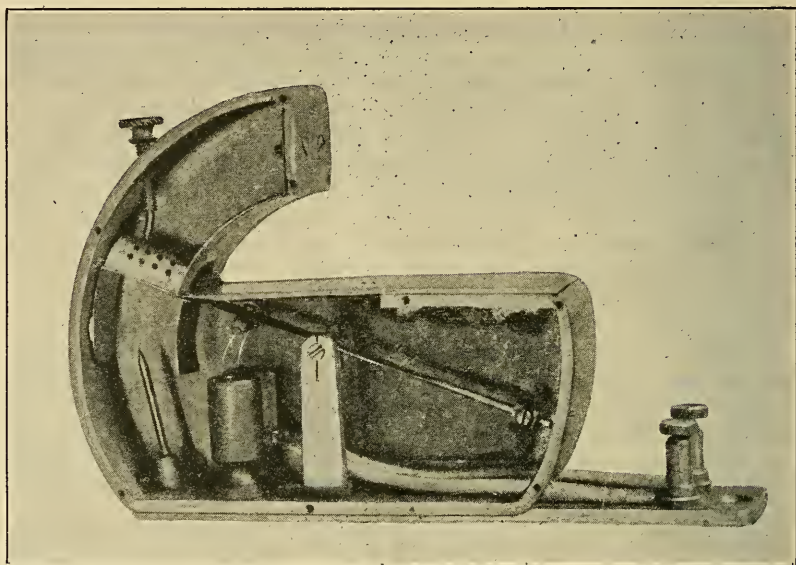


FIG. 1.—Apparatus for recording by electrical contact the ingress of bees into the hive

Since this device, in the course of this investigation, has shown certain undesirable features, it remains, in a search for the ideal counting device, to consider briefly the possibility of counting bees by means of the amplification of a current whose circuit is closed by the body of the bee itself.

In discussing the possibility of this method with the writer, radio experts have suggested that it might be better to get the bee to pass between the plates of a small condenser and thus to vary its dielectric constant, and then to use this variation to record the passage of the bee. Assuming that expense is of no consideration, it is still questionable whether this method would have any advantage over the one used in this investigation. Some device would be needed before and after the condenser to regulate the passage of the bees, and these obstructions might be as great as or greater than that offered by the

present device, so that the only advantages to be gained, provided the principle could be developed to do away with occasional multiple recording by the same bee, would be a less frequent necessity for cleaning the gates, and perhaps a relatively larger capacity for each gate.

THE COUNTING DEVICE

If the bee-escape method of counting had proved successful, it would have been necessary to use a weak current for making the records. The first type of counter tried consisted of an ordinary alarm clock with the balance wheel removed. A piece of soft iron was then attached to the escape lever and an electromagnet was placed on the framework. When this magnet was excited by the closing of the circuit by the bee, it attracted the soft iron on the escape lever and allowed one tooth of the escape wheel to pass. When contact was broken, a light spring brought the lever back to its first position. Thus one contact corresponded to one vibration of the original balance wheel, and by knowing the beat of the clock it was possible to count the exits or entrances from any particular gate merely by reading the "time" on the dial.

This instrument, though crude, proved promising, but was not adopted for the present investigation. With the balance device adopted, a much stronger current can be used. It was therefore possible to use a telephone-message register, already manufactured and available, which consists of a simple cyclometer actuated by an electromagnet, operating on a higher voltage (about 16 or 18 volts) than would be required for the counter made from the clock.

ARRANGEMENT OF THE APPARATUS

For convenience in handling, each set of gates was attached to a board hinged to the end of a 10-frame Langstroth hive body, so that the instruments could be swung away from the hive and yet not be detached entirely. When these boards were clamped to the hive, so as to close the entrance, the outgoing gates were above and somewhat in front of the incoming ones, the actual exit apertures being about 2 inches above the row of entrance apertures. This arrangement proved very satisfactory, because it minimized the possibility of the bees holding down the tunnels of outgoing gates by attempting to enter the hive through them.

A false bottom-board within the hive conducted the bees to the outgoing instruments, and an outside alighting-board led the returning bees to the ingoing tunnels. The incoming bees, on passing through the contact mechanism, entered a small chamber below the inside false bottom-board, and to enter the brood chamber proper they passed through slots in this false bottom-board. A strip of queen-excluding zinc was placed behind the outgoing gates and above the slots at an angle of about 45°, sloping upward and backward. This forced the bees in carrying their dead to drop them, so that the dead bees fell through the slots in the false bottom-board to a position behind the incoming gates, where they could conveniently be removed and counted.

Ventilation was at first provided by means of a maze which admitted air but no light through a slot in the bottom-board. This

arrangement proved satisfactory until some time in June, when a change was necessitated by the peculiar behavior of the bees during hot weather. Several changes were tried, but the plan that appeared to give the greatest satisfaction was to close this lower ventilator and to remove one of the ingoing gates, the remaining 14 gates being spaced more widely, thus allowing more of the hive odor to escape between the gates. Ventilation at the top of the hive was also provided during the hottest weather.

A weatherproof telephone cable led the wires from the contact devices to the recording counters attached to a table in the laboratory, about 50 feet from the hive. Two storage batteries furnished the current, these being recharged periodically by means of a rectifier.

During the portion of each day when the bees were flying, the following observations were recorded without interruption at exactly 15-minute intervals: Records of outgoing and incoming bees; weight of the entire hive with attached apparatus; temperature in the shade adjacent to the hive; anemometer record of the wind which had passed since last reading; and notes on the weather conditions, including the degree of cloudiness. These readings usually began at about 5.30 a. m. and continued until about 8 p. m., depending somewhat on the season.

PROBLEMS ON WHICH INFORMATION MAY BE OBTAINED BY A DEVICE FOR COUNTING FLIGHTS

If an accurate count could be obtained of the exits from and entrances to a hive without interfering unduly with the normal flight activities of the bees, the data obtained would throw some light on the following problems:

1. Perhaps the most important would be the responses of bees to various honey flows, especially to those that are not heavy enough to be reflected very markedly in the weight of the hive. Information regarding this problem would undoubtedly assist in a study of nectar secretion, especially with reference to the time of day and the relative amount of secretion.

2. The responses of bees to various meteorological conditions, such as intensity of light, temperature, wind, rain, and electrical disturbances.

3. Average duration of the flight, its variation with the honey flows and the general atmospheric conditions.

4. The daily average number of trips per bee to the field, ascertained by manipulating the hive so as to get a census of the field bees on any particular day.

5. The possible responses of bees to sounds, odors, and other stimuli.

6. The death rate of the colony, the comparative numbers which die in the field and in the hive, and the factors which contribute to an increased death rate.

7. The effect on bees of the time of application of certain poisonous insecticides in horticultural practice.

8. The relative economic importance of predatory wasps, other enemies, and adult bee diseases, information regarding which might be obtained by correlating flight data with the normal death rate.

THE CONDITIONS OF THE EXPERIMENT

In order to care for the great rush of bees on the approach of storms or to allow for possible clogging of some of the gates, it was necessary to provide such conditions that the gates would be worked normally much below their full capacity. This was done by employing a colony of bees of comparatively small size. When the taking of the records was begun in April, this colony, headed by a 1-year-old Italian queen, was in a hive composed of two bodies. The colony had about 5 pounds of bees, brood to fill four frames completely (Langstroth size), and seven frames containing honey. The remaining frames were nearly empty. When the colony was examined in detail on May 25, seven frames of brood and two frames containing eggs were present. A considerable number of larvæ then showed symptoms of sacbrood. On the termination of the experiment at the end of July there were about 3 pounds of adult bees, three frames of brood, and a serious shortage of honey. Some of the larvæ dead of sacbrood were not yet cleaned out.

To prevent so far as possible the drifting of other bees to this colony, the hive was set up in an isolated position about 36 feet from another colony and about 100 feet from the main yard on the west side of the bee culture laboratory, Somerset, Md. It was shaded by the building until 9 to 10 a. m. and by a tall tree in the afternoon.

During April, 1922, the hive did not show any days of gain in weight due to incoming nectar. In this region the main honey flow comes rather early, the two main nectar sources being black locust (*Robinia pseudacacia*) and tuliptree (*Liriodendron tulipifera*). These species yield nectar in May, usually early in the month, followed by a small amount of nectar from white clover (*Trifolium repens*) and from other plants of minor value for nectar. Usually by the end of June in this region a dearth of nectar occurs and lasts until fall, so that there is nothing for the bees to gather during midsummer, unless, as sometimes happens, there is a production of honeydew.

In the season of 1922 the first gain in weight from black locust occurred on May 3, but a heavy rain on the night of May 14 brought this honey flow to a sudden close. The tuliptree began to bloom on May 7, and the last gain from this source occurred on May 28. During this period of substantial honey flow there was no gain on five days because of rain. Small gains in weight from incoming pollen, with some nectar, took place in this colony on June 8, 10, and 17. All the other days throughout June and July showed a daily loss in weight, with the exception of July 16, when in the evening the hive had exactly regained its morning weight. The highest daily gain recorded for this colony was 1.440 kilograms, and on two other days the gain exceeded a kilogram. If a colony of full strength could have been employed the gains in weight would have been larger.

Of the 50 days on which this colony showed a loss in weight and on which rains did not invalidate the scale readings by the accumulation of moisture on the hive, 9 days showed a loss of 10 to 90 grams, 15 a loss between 100 and 190 grams, 8 between 200 and 290 grams, 13 between 300 and 390 grams, and 4 between 400 and 490 grams, with 1 day showing a loss of 610 grams. The experiment was discontinued before the beginning of the autumn honey flow.

For convenience in compiling the data, the quarter-hourly readings were recorded by means of a typewriter on cards of three different colors, blue being used for the outgoing data, yellow for the incoming data, and white for all other records and general notes. The differences between the successive readings and other data were obtained at a later date by the use of an adding machine. The long days, with frequent observations and the dismantling and cleaning of some of the gates in the evenings to get the apparatus ready for the following day, not only necessitated two observers but also rendered it impossible to make compilations during the active season of work.

FACTORS INTRODUCING ERRORS IN THE COUNT

With any untried experimental mechanism consisting, as this did, of many units, each unit in turn possessing parts having defects either of construction or of design, it is too much to expect perfect accuracy during the first season. Before discussing the magnitude of the experimental error produced by these deficiencies, it is desirable so far as possible to know the manner in which this error arises.

1. After observing the passage of about 2,000 bees through the early experimental model, it was thought that a tunnel had been devised which although allowing only one bee to pass at a time, would cause little inconvenience to the insect and would avoid as much as possible the scraping off of the load of pollen as the bee passes through the device. However, further experience with the full set of gates on the hive showed that some of the tunnels would occasionally allow two bees to pass at one time. Sometimes the two bees would get through and establish only one electrical contact, but they might cause two or even more contacts because of the irregular manner in which the tunnel fell under their weight, the movement being impeded by the pressure of their bodies against the stationary surfaces of the apparatus. Under normal weather conditions this difficulty was confined almost entirely to the outgoing gates, as the stimulus urging the bees into the outgoing channels was apparently much stronger than that attracting them into the ingoing tunnels. By darkening the glass windows and reducing the dimensions of the tunnels, this error was reduced to a minimum. Rebuilding all these tunnels was a tedious operation, consumed a great deal of time, and could be done only gradually, so that the early records show a greater error from this cause than the later ones.

2. Rebounding of the empty tunnel so as to form a second contact occurred occasionally if the adjustment of the counterweight was too delicate or if it had been rendered so by débris or pollen collecting in the tunnel.

3. Débris dropped or propolis placed by the bees in the clearance between the movable and stationary parts may cause double contacts by slowing down the speed of the tunnel in its fall; but when the quantity of débris became so large that the tunnel ceased to function, no error was introduced.

4. The voltage made necessary by the adoption of the telephone-message register unfortunately caused a considerable amount of oxidation on the surface of the mercury through arcing. In spite of frequent cleaning of the surfaces of mercury, this occasionally gave

some trouble in case the mercuric oxide collected as a flocculent mass on the platinum points. Under such circumstances the weight of the bee is no longer sufficient to overcome the greater displacement of mercury now necessary, and multiple contacts may result. This error was apparently eliminated by adjusting the apparatus so as to bring the mercury cups closer to the fulcrum, giving the bee a greater moment than this opposing force.

5. The bees about to enter the tunnel may push against the closed inner door (especially if its clearance is large) and may occasionally produce multiple contacts when the tunnel is either on its downward or on its upward stroke.

6. A bee pushing hard against the glass of an outgoing gate may produce multiple contacts by preventing a tunnel from falling rapidly past its critical point. Errors from this cause and from pushing against the closed inner door were very much reduced by darkening the glass on the gates (p. 8).

7. Bees clawing at the closed outer door of the device may bring the tunnel down far enough to form an electrical contact, especially if the doors are roughened by dirt or propolis or by a corrosion of the surface of the metal. Error from this source was peculiar to the ingoing gates, for on only two occasions was it observed on an outgoing gate. An attempt was made to eliminate this source of error by placing small metal cups over the exit hole so that clawing could take place only in an upward direction.

8. The segments of some of the recording cyclometers would sometimes bind against each other, thus failing to record the contacts when the magnet was excited by the passage of a bee. This necessitated some readjustments of the cyclometers.

9. The cleaning of the gates in the evening, after the day's records had been taken, necessitated the use of an artificial light, which on warm nights attracted some bees from inside the hive. These might remain outside all night, thus introducing an error on the following day.

10. The clustering out of the bees in the warm weather following the main honey flow was one of the most disturbing features of this investigation. On many days, records which were normal during the early part of the day were rendered valueless later on through the clustering out of the bees in the afternoon. At the same time this clustering out occurred throughout the apiary.

11. In the construction of the outgoing gates a small strip of metal was left between the outer aperture and the lower edge of the glass window, which was sometimes grasped by the bee in its fall, giving rise to multiple contacts.

12. A small error was caused by the actual drifting of the bees. This was apparent on colder mornings when the other hives in the apiary were active and the experimental one had not yet commenced its activity.

It is clear from the preceding list of causes of errors that with the exception of No. 8, and sometimes of No. 1, all these factors have a tendency to increase rather than decrease the recorded exits and entrances of the bees. With the experience gained in the 1922 season in the design and handling of this apparatus, the writer is convinced that, with the exception of Nos. 2 and 3, where *débris* is the cause of error, all these factors may eventually be eliminated.

On any particular day the magnitude of the experimental error depends upon the combination of factors operating on that day. On 89 of the 105 days on which records were taken, omitting records accidentally falsified by various causes, it appears that out of every 100 of the 2,434,666 contacts formed by outgoing bees, 96.84 returns were registered. On 37 of these days the records show more bees coming back than were recorded as going out, and these so-called gains in the returns give an obvious error of at least 1.86 per cent for the days recorded in Table 1. These 37 days were distributed as follows, and showed for every 100 exits daily the following average returns for each group: April, 4 days, 111.99; May, 10 days, 104.50; June, 7 days, 104.87; July, 16 days, 104.29. These data give some idea of the magnitude of the daily experimental error which may take place. The percentage returns on these days varied from 100.08 to the maximum, one day in April, when they were as high as 127.81.

If the days are selected on which the apparatus worked well, and the daily percentage of error which occurred, so far as it could be determined, is kept in mind, the general utility of the curves obtained from these data for such purposes as a study of the effect of external environmental factors is little affected by this error. For a study of the average duration of each flight, where a greater degree of accuracy is essential, a closer selection of data is necessary. Referring, therefore, to the outline of the problems on which it is hoped that such an apparatus may give some information, it is found that this apparatus is performing its function as regards four of them, one of which has been rated as the most important in this investigation.

FACTORS INFLUENCING THE FLIGHT

The various activities of the colony population are so interrelated that in a study of any one factor, influencing any particular activity such as flight, it sometimes becomes exceedingly difficult to gauge its exact influence, or even to give the right factor the credit for the behavior observed. Since it is possible not only to observe the variations in flight produced by changes in the intensity of any single factor throughout the course of a day, but also to gauge to a certain extent the gross influence of this factor on the day's flight as a whole, it is necessary in a study of any factor to make use of both of these sources of information. To ascertain the gross influence of any factor, a general survey of the whole period in which records were made is necessary.

THE SEASONAL SURVEY

In order to obtain a comprehensive picture of the daily flight activities throughout the season, it is necessary to plot a curve (fig. 2) of the total daily exits from the hive (Table 1). As might be expected, this curve has several high points, representing the data for those days when the conditions for flight were at an optimum for the period of the season in which they occur. A day that is considered an optimum for April would very naturally be a bad flight day for June or July; therefore in a study of any particular day a comparison must be made between this day and another in close proximity to it, when presumably, or as far as can be ascertained, the field conditions, internal conditions of the colony, and the number of

field bees are but little different. By connecting these high points in the flight curve, there is obtained a second curve (fig. 2) indicating the optimum seasonal flight possible. This optimum curve,

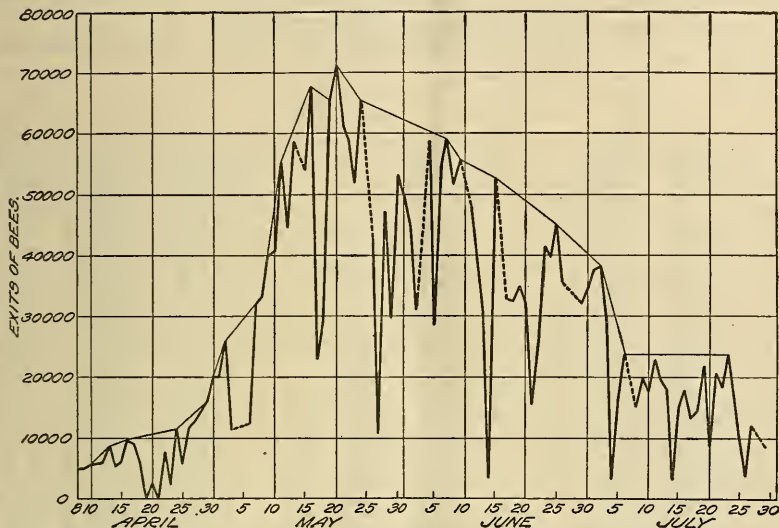


FIG. 2.—Total number of exits of bees from hive on each day during the period of investigation. Dotted lines indicate days on which no records were taken

from the end of April to the first week of the honey flow in May, shows a fairly steep ascent (rising from 10,000 or 20,000 exits to 60,000 or 70,000 exits daily), indicative of the increasing number of field bees and their increased number of trips on the advent of the honey flow.

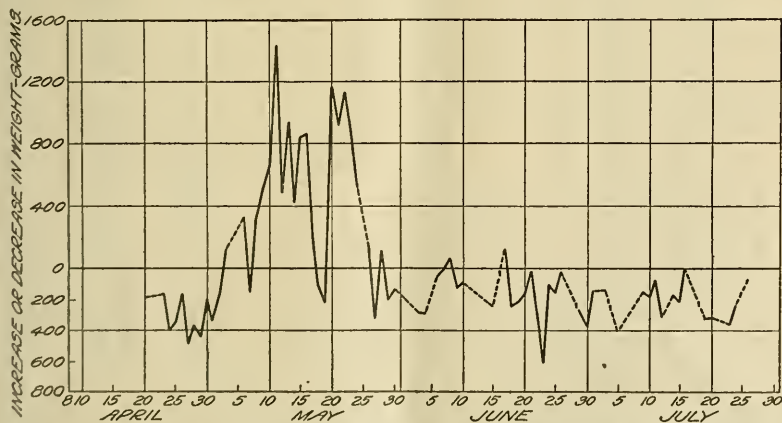


FIG. 3.—Graphical record of daily gains and losses in weight of the hive. The dotted portions of the curve indicate days on which weighings were not made, or were vitiated by moisture on the hive

Figure 3 illustrates another phase of the seasonal survey by presenting the increase or decrease in weight of the hive during the greater part of the period of investigation.

TABLE 1.—A seasonal survey of some observations for entire days

Date	Total exits	Total returns	Loss	Gain	Per cent returns are of exits	Loss or gain in weight of hive ¹	Average load per returning bee ²	Per cent of possible sunshine	Temperature in shade during period of observations			
									Minimum		Maximum	
						Grams	Milli-grams		°C.	°F.	°C.	°F.
Apr. 10...	5,479	6,410	-----	931	116.99	-----	-----	100	19.5	67.10	31	87.80
11...	5,609	5,289	320	-----	94.29	-----	-----	63	19.5	67.10	27	80.60
12...	6,052	6,183	-----	131	102.16	-----	-----	85	13.25	55.85	20.5	58.90
14...	5,150	4,672	478	-----	90.72	-----	-----	7	15	59	19	66.20
15...	5,825	5,662	163	-----	97.20	-----	-----	91	14.5	58.10	17.5	63.50
16...	9,757	8,537	1,220	-----	87.50	-----	-----	100	7.25	45.05	22	71.60
17...	8,318	7,940	378	-----	95.46	-----	-----	5	14	57.20	21	69.80
18...	6,086	5,943	143	-----	97.65	-----	-----	10	15.5	59.90	21	69.80
19...	17	15	2	-----	88.24	-----	-----	0	7.5	45.50	10	50
20...	2,465	2,489	-----	24	100.97	-190	-----	100	7	44.60	15	59
21...	34	30	4	-----	88.24	-----	-----	18	3	37.40	10	50
22...	7,439	6,822	617	-----	91.71	-----	-----	100	0.5	32.90	14	57.20
23...	2,262	1,955	307	-----	86.43	-180	-----	78	4	39.20	14	57.20
24...	11,288	10,847	441	-----	96.09	-410	-----	100	1.5	34.70	17	62.60
27...	12,501	10,557	1,944	-----	84.44	-480	-----	41	13	55.40	30	68
28...	14,340	12,005	2,335	-----	83.72	-370	-----	52	7	44.60	17	63.60
29...	15,964	20,404	-----	4,440	127.81	-430	-----	95	3	37.40	19	66.20
30...	20,023	20,558	3,465	-----	82.69	-200	-----	100	8.5	47.30	22	71.60
May 1...	19,941	20,063	-----	122	100.61	-320	-----	100	8.5	47.30	22	71.60
2...	26,475	26,099	376	-----	98.58	-150	-----	94	11	51.80	27	80.60
3...	11,389	10,288	1,101	-----	90.33	110	-----	6	16	60.80	20	68
7...	31,926	31,185	741	-----	97.68	-150	-----	94	18	64.40	28	82.40
8...	33,253	33,687	-----	434	101.31	320	9.5	100	15	59	25	77
9...	39,765	39,313	452	-----	98.86	500	12.7	80	12	53.60	24.5	76.10
11...	55,231	59,658	-----	4,427	108.02	1,440	24.1	100	16	60.80	30	86
12...	44,931	48,875	-----	3,944	108.78	490	10.0	46	17	62.60	24	75.20
13...	50,869	58,887	-----	8,018	115.76	940	15.9	64	16	60.80	26	78.80
15...	54,061	54,528	-----	467	100.86	850	15.6	76	14	57.20	25	77
16...	67,863	60,377	7,486	-----	88.97	870	14.4	87	11	51.80	28.5	83.30
17...	22,992	23,218	-----	226	100.98	220	9.5	0	14	57.20	20	68
18...	29,247	30,478	-----	1,231	104.21	-----	-----	0	18	64.40	20.75	69.35
19...	65,407	66,898	-----	1,491	102.28	-----	-----	84	15	59	23.25	73.85
20...	71,008	66,844	4,164	-----	94.14	1,170	17.5	68	10	50	25.5	77.90
21...	61,438	56,135	5,303	-----	91.37	920	16.4	75	14	57.20	29	84.20
22...	49,078	44,597	4,481	-----	90.87	1,130	25.3	79	17	62.60	30	86
23...	51,854	48,268	3,586	-----	93.08	890	18.4	88	15.5	59.90	30	86
24...	65,259	63,395	1,864	-----	97.14	560	8.8	99	15	59	28	82.40
26...	42,138	38,356	3,782	-----	91.02	130	3.4	23	19	66.20	26	78.80
27...	10,588	10,030	558	-----	94.73	-330	-----	6	14	57.20	21.5	70.70
28...	47,397	42,663	4,734	-----	90.01	100	2.3	94	17	62.60	23	73.40
29...	51,640	49,338	2,302	-----	95.54	-200	-----	99	8.5	47.30	26	78.80
30...	52,987	49,534	3,453	-----	93.48	-130	-----	100	13	55.40	27	80.60
31...	49,474	50,580	-----	1,106	102.24	-80	-----	70	13	55.40	27	80.60
June 1...	44,882	45,693	-----	811	101.81	-----	-----	0	17	62.60	24	75.20
2...	30,852	28,499	2,353	-----	92.37	-----	-----	14	20	68	26	78.80
4...	58,564	56,128	2,436	-----	95.84	-290	-----	77	16.5	61.70	30	86
5...	28,432	29,830	-----	1,398	104.92	-----	-----	3	19	66.20	24	75.20
6...	54,772	53,883	889	-----	98.38	-50	-----	59	20	68	31	87.80
8...	51,531	49,607	1,924	-----	96.27	60	1.2	54	19	66.20	31.5	88.70
9...	55,678	52,066	3,612	-----	93.51	-120	-----	45	21	69.80	28	82.40
11...	48,043	50,524	-----	2,481	105.16	-90	-----	81	22	71.60	31.5	88.70
12...	39,231	39,915	-----	684	101.74	-----	-----	97	20.5	68.90	28	82.40
13...	30,423	29,266	1,157	-----	96.20	-----	-----	66	10	50	22	71.60
14...	3,399	3,501	-----	102	103.00	-----	-----	0	17	62.60	18	64.40
21...	17,980	20,447	-----	2,467	113.72	-20	-----	54	18	64.40	29	84.20
22...	25,654	26,617	-----	963	103.75	-340	-----	94	17	62.60	24.5	76.10
23...	41,361	37,244	4,117	-----	90.05	-610	-----	91	15	59	28.5	83.30
24...	39,667	36,505	3,162	-----	92.03	-110	-----	81	12	53.60	31.5	88.70
25...	45,182	42,060	3,122	-----	93.09	-160	-----	96	18.5	65.30	32.5	90.50
26...	35,789	31,046	4,743	-----	86.75	-30	-----	74	18	64.40	29.5	85.10
29...	32,173	25,941	6,232	-----	80.63	-300	-----	61	20.5	68.90	29	84.20
30...	34,974	30,627	6,167	-----	82.37	-380	-----	98	19	66.20	33	91.40
July 1...	37,834	38,806	7,208	-----	80.95	-110	-----	64	23	73.40	34	93.20
2...	38,339	29,880	8,459	-----	77.94	-----	-----	64	20	68	35	95

¹ The hive was not on scales for the first few days of observation. On some later days an accumulation of moisture on the tops and on the bottom-board introduced erroneous records of weight, and such days have been omitted from this table.

² Figures in this column indicate the minimum limit of the average loads for the day and not the actual average load. Since consumption of stores and evaporation continue throughout the day, the actual average load can not be obtained from weights of the entire hive. This limit can only be determined for those days when the hive showed a gain due to incoming nectar.

TABLE 1.—A seasonal survey of some observations for entire days—Con.

Date	Total exits	Total returns	Loss	Gain	Per cent returns are of exits	Loss or gain in weight of hive	Average load per returning bee	Per cent of possible sunshine	Temperature in shade during period of observations			
									Minimum		Maximum	
						Grams	Milli-grams		° C.	° F.	° C.	° F.
July 3----	28,918	24,074	4,844	-----	83.25	-100	-----	53	22	71.60	32.5	90.50
4----	3,206	2,506	700	-----	78.17	-----	-----	0	19	66.20	22	71.60
5----	16,384	14,404	1,980	-----	87.92	-410	-----	24	15	59	25	77
6----	23,954	22,635	1,319	-----	94.49	-360	-----	94	13.5	56.30	28	82.40
8----	15,267	14,737	530	-----	96.53	-----	-----	57	20	68	31.5	88.70
9----	19,897	20,003	-----	106	100.53	-150	-----	82	20.5	68.90	31.5	88.70
10----	17,619	17,305	314	-----	98.22	-180	-----	72	21	69.80	29	84.20
11----	22,973	21,784	1,189	-----	94.82	-80	-----	59	21.5	70.70	31	87.80
12----	19,509	20,281	-----	772	103.96	-320	-----	100	23.5	74.30	35	95
13----	17,947	17,931	16	-----	99.91	-----	-----	68	23	73.40	34	93.20
14----	3,302	3,148	154	-----	95.34	-170	-----	0	19.5	67.10	23	73.40
15----	14,976	16,182	-----	1,206	108.05	-220	-----	46	18	64.40	29	84.20
16----	17,935	18,968	-----	1,033	105.76	000	-----	53	19.5	67.10	28	82.40
17----	13,284	14,808	-----	1,524	111.47	-----	-----	71	20	68	33	91.40
18----	14,372	14,498	-----	126	100.88	-----	-----	58	20.5	68.90	34.25	93.65
19----	21,502	21,828	-----	326	101.52	-340	-----	35	21.5	70.70	31	87.80
20----	8,956	9,131	-----	175	101.95	-330	-----	6	20	68	25.5	77.90
21----	20,916	21,535	-----	619	102.96	-340	-----	100	15	59	30	86
22----	18,376	19,389	-----	1,013	105.51	-----	-----	66	21	69.80	30	86
23----	23,881	24,974	-----	1,093	104.58	-370	-----	85	19	66.20	32	89.60
24----	17,460	18,006	-----	546	103.13	-240	-----	85	22	71.60	32.25	90.05
25----	10,079	10,087	-----	8	100.08	-----	-----	31	20	68	29	84.20
26----	3,687	3,963	-----	276	107.49	-70	-----	3	19	66.20	24	75.20
27----	12,003	13,054	-----	1,051	108.76	-120	-----	49	20	68	28	82.40
29----	8,683	8,861	-----	178	102.05	-250	-----	80	15	59	29.5	85.10
Total----	2,434,666	2,357,769	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Throughout the honey flow and for the next five weeks after its close, the total daily exits show a gradual falling off, until the sixth week, when there is a rather sudden falling off from 40,000 to a number fairly constant for a period throughout July, during which the total number of possible daily exits is about one-third of those occurring on the best days in the honey flow in May. This indicates that the emergence of young bees is not sufficient to replace the high death rate following the honey flow, until the majority of these old bees have died off. There is, of course, every gradation in flight from the best days in the honey flow to other days on which practically no flights take place.

It is noticed that on heavily overcast days, with or without occasional precipitation, the low intensity of light seems to be the strongest factor inducing the bees to stay at home. Days that are bright and sunny, but ushered in by a low morning temperature, show some remarkable differences in the totals for the day, amounting in certain cases to as much as 40 to 50 per cent of the possible flight for the period. For each day throughout the season that does not come up to the optimum flight curve, some factor or group of factors has been at play, modifying the flights to a less or greater degree. Such data, however, do more than substantiate the well-known facts concerning bee behavior indicated above, for they also give a means of measuring the exact influence of any factor or group of factors.

INFLUENCE OF STORMS AND RAIN

The period of the season of 1922 in which these data were obtained included many bright days on which storms occurred during the course of the afternoon, giving an excellent opportunity to study the behavior of the bees on the approach of a storm; in fact, for the purposes of a brief general study of flight activities, there were too many such days.

The influence of a storm is well shown by the data for a single day (Table 3, and fig 4.) The records on which this curve is based were

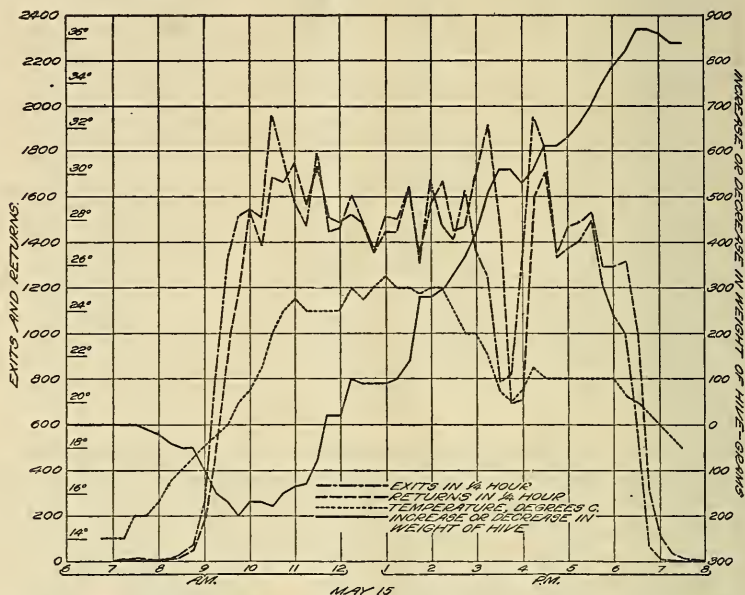


FIG. 4.—Flight, temperature and hive-weight data for May 15, 1922, showing the effect of a threatened storm (2.30–4.15 p. m.) on flights

taken on May 15, a bright, sunny day until the afternoon. The following chronological data show the weather conditions:

Time	Weather conditions
2.30	A clouding over is noticed.
2.45	The very much darkened sky indicates the sudden approach of a storm.
3.00	It is thundering, and an increase in the number of heavily laden nectar-carrying bees is noted at the gates.
3.15	A gusty wind is blowing, precipitation being expected any minute.
3.30	The storm is passing from a westerly direction to a southerly. The very dark nucleus of the storm, where precipitation appears to be taking place, is from 3 to 4 miles away.
3.45	The air is calmer, the storm having passed without any precipitation.
4.00	The sun is shining occasionally and for short intervals.
4.15	The sun is shining steadily, and it has cleared up completely. [This condition continued for the remainder of the day.]

No better example of the sudden approach of a storm with all its symptoms to the very point of precipitation, but without actual precipitation, could have been obtained.

TABLE 2.—Length of bees' flights in minutes per trip to and from the hive

Date	Period of day's flights	Length of period	Flights during period		Number of times flight was ascertained	Average number in field flights	Probable error of average in round numbers ($\pm$)	Probable error of average expressed in per cent of average ($\pm$)	Average duration of trips	
			Exits	Returns					Based on exits	Based on returns
		Minutes							Minutes	Minutes
Apr. 15	2.00- 5.00	180	2,597	2,572	4	148	9	6.21	10.26	10.36
20	12.30- 2.00	90	1,100	1,130	4	112	8	7.26	9.16	8.92
May 8	11.30- 4.30	300	16,761	16,801	11	1,974	9	1.46	35.33	35.25
9	11.00- 6.00	420	29,176	29,200	23	2,980	54	1.83	42.90	42.86
15	9.45- 3.00	315	32,492	32,265	22	1,567	28	1.78	15.19	15.30
15	4.15- 5.15	60	5,920	6,023	5	1,148	17	1.49	11.63	11.43
17	12.30- 2.30	120	6,408	6,678	9	776	27	3.50	14.53	13.94
20	12.00- 2.00	120	10,988	10,006	9	2,654	30	1.12	12.19	13.81
22	10.30-12.45	135	19,508	8,973	10	2,713	41	1.52	138.19	140.80
June 1	8.15- 2.15	360	29,687	29,322	25	1,732	66	3.83	21.00	21.26
6	9.00-11.00	120	11,658	11,027	9	3,283	74	2.25	133.79	135.73
6	11.15-12.00	45	4,299	3,117	4	4,321	167	3.88	145.23	162.38
6	12.15- 4.00	225	20,094	19,934	16	5,674	41	0.73	163.52	164.03
12	8.00- 9.30	90	4,553	3,257	7	1,817	116	6.38	35.90	50.18
12	9.45- 4.45	420	28,303	28,422	29	3,683	46	1.25	54.64	54.41
25	10.30-12.45	135	19,128	9,167	10	4,170	21	0.51	61.66	61.40
July 9	10.30- 3.30	300	11,103	11,314	21	3,571	37	1.04	96.49	94.69
10	10.45- 3.30	285	9,166	9,064	20	3,305	31	0.94	102.73	103.92
12	9.15- 3.00	345	13,158	13,442	24	1,941	79	4.06	50.89	49.81
13	9.30- 2.30	300	11,087	10,873	21	2,389	32	1.33	64.64	65.91
18	9.15-12.30	195	7,931	8,190	14	1,654	48	2.91	39.53	39.28
18	3.15- 4.45	90	638	637	7	138	4	2.70	19.47	19.49
24	9.00- 3.00	360	10,397	10,481	25	719	20	2.77	24.89	24.69
25	9.00-10.15	75	1,501	1,512	5	534	9	2.73	26.63	26.44
25	10.45- 2.15	210	4,581	4,405	15	980	20	1.01	44.88	46.67
25	11.30-12.00	30	851	847	3	1,072	7	0.70	37.79	37.97
25	12.15- 1.00	45	898	731	4	866	32	3.69	43.39	53.31
25	1.15- 2.15	60	1,274	1,280	5	1,070	9	0.86	50.39	50.16
29	9.45- 3.45	360	5,822	6,357	25	505	12	2.42	31.23	28.60

¹ Correction applied for bees registered as lost.

TABLE 3.—Record of exits and returns, total and per quarter hour, and of bees in the field, May 15, 1922

Time	Total exits	Total returns	Bees in field	Exits in one-quarter hour	Returns in one-quarter hour	Time	Total exits	Total returns	Bees in field	Exits in one-quarter hour	Returns in one-quarter hour
			Number	Number	Number				Number	Number	Number
7.00	0	0	0	0	0	1.30	27,731	25,951	1,780	1,645	1,641
7.15	7	0	0	7	0	1.45	29,042	27,289	1,753	1,311	1,338
7.30	7	15	—8	0	15	2.00	30,708	28,865	1,843	1,666	1,576
7.45	9	26	—17	2	11	2.15	32,181	30,541	1,640	1,473	1,676
8.00	12	31	—19	3	5	2.30	33,595	31,989	1,606	1,414	1,448
8.15	19	43	—24	7	12	2.45	35,223	33,457	1,766	1,628	1,468
8.30	43	59	—16	24	16	3.00	36,567	35,162	1,405	1,344	1,705
8.45	110	108	2	67	49	3.15	37,807	37,077	730	1,240	1,915
9.00	367	280	87	257	172	3.30	38,590	38,577	13	783	1,500
9.15	1,225	798	427	858	518	3.45	39,410	39,270	140	820	693
9.30	2,557	1,727	830	1,332	929	4.00	40,740	39,979	761	1,330	709
9.45	4,075	2,897	1,178	1,518	1,170	4.15	42,658	41,575	1,113	1,948	1,596
10.00	5,621	4,448	1,173	1,546	1,551	4.30	44,500	43,278	1,222	1,812	1,703
10.15	7,131	5,834	1,297	1,510	1,386	4.45	45,830	44,634	1,196	1,330	1,356
10.30	9,091	7,526	1,565	1,960	1,692	5.00	47,204	46,105	1,099	1,374	1,471
10.45	10,864	9,187	1,677	1,773	1,661	5.15	48,608	47,598	1,010	1,404	1,493
11.00	12,437	10,939	1,498	1,573	1,752	5.30	50,105	49,132	973	1,497	1,534
11.15	13,905	12,508	1,397	1,468	1,569	5.45	51,315	50,421	894	1,210	1,289
11.30	15,696	14,246	1,450	1,791	1,738	6.00	52,394	51,718	676	1,079	1,297
11.45	17,138	15,560	1,578	1,442	1,314	6.15	53,392	53,035	357	998	1,317
12.00	18,597	17,046	1,551	1,459	1,486	6.30	53,987	54,052	—65	595	1,017
12.15	20,200	18,577	1,623	1,603	1,531	6.45	54,048	54,366	—318	61	314
12.30	21,686	20,065	1,621	1,486	1,488	7.00	54,058	54,474	—416	10	108
12.45	23,063	21,423	1,640	1,377	1,358	7.15	54,061	54,513	—452	3	39
1.00	24,577	22,867	1,710	1,514	1,444	7.30	54,061	54,528	—467	0	15
1.15	26,086	24,310	1,776	1,509	1,443						

It is noticed that the bees did not respond to the cloudiness at 2.30 p. m.; but when the sky darkened at 2.45 p. m. the curve representing incoming bees immediately began its rapid ascent and the outgoing bees showed a decrease, the divergence of the two curves continuing at an equal rate until 3.15 p. m., when the greatest number of returning bees had entered the hive. The climax of the threatening storm was just previous to 3.30 p. m., when the curve of outgoing bees reached its lowest point, and all but 13 of the bees in the field had entered the hive. At this point the surprising fact is revealed by this day's record that, although the storm was so severe as momentarily to send all the field bees back to the hive, the impulse of the bees to go to the field while the secretion was good was so strong that in the half hour in which the climax of the threatening storm occurred as many as 50 to 75 per cent of the bees, which were going out under optimum conditions for this day, were still leaving the hive. The quick response of the bees, this time to the gradual but rapidly improving conditions of the weather, is seen from 3.30 to 4.15 p. m., when normal activity was resumed. It is interesting to speculate as to just what feature of the storm contributed most to this behavior in the flight of the colony. Was it drop in temperature, variation in light or atmospheric pressure, difference in humidity, intensity of the wind, or general change in the electrical conditions of the atmosphere? Unfortunately, not all of these questions can be answered definitely as yet.

Of all these factors, temperature and light varied most. If temperature had been the chief cause, the flight might have been expected to remain low after the storm, since the temperature remained low for the remainder of the afternoon. The response to the change in light, both its increase and its decrease in intensity, can be so closely correlated with the flight activity that this may be safely considered the chief cause of the variation.

Comparing this day with May 13 (see Table 1), when the number of field bees was perhaps slightly less and on which there were 58,887 returns, we find that there were only 54,528 on May 15, which shows that the threatening storm of the latter day reduced the total flights by at least 7.40 per cent. On the assumption that the nectar conditions on these two days were identical, this represents a loss of 69.58 grams, due to this clouding over. Actually 90 grams less nectar was gathered, which would indicate that there was little or no difference in the nectar conditions on these two days.

Comparing May 15 with May 16, which was bright and sunny all day, with 60,377 returns, it is found that the decrease in total flight on May 15, apparently due to this storm, was 9.69 per cent. Only 20 grams more nectar was gathered on the 16th, showing that although a good day it was not quite so good a day for nectar secretion as either May 13 or May 15. This indicates that the afternoon storm of May 15 reduced the day's flight by from 7.40 to 9.69 per cent with, of course, a corresponding reduction in the day's gathering compared with an optimum secretion.

The record of July 8 (fig. 5) is typical of the flight when actual precipitation occurs. This was a bright, sunny day until 12.30 p. m., when a general clouding over occurred. The following data show the progress of this storm:

Time

Weather conditions

1.00 A few drops are falling.

1.15 The sprinkling has ceased.

1.30 Thundering, sky very dark, beginning to rain gently.

1.45 Light rain falling.

2.00 Raining heavily.

2.30 The rain has stopped.

4.30 The sky has cleared, but the sun is obstructed by some clouds.

5.00 The sun is shining brightly.

6.00 The sky is again clouded. [This condition persisted until dusk.]

This was in a period of the year when, on account of the scarcity of nectar, a relatively larger percentage of the field bees are absent from the hive at any particular time. On the approach of a storm, therefore, their homeward rush produces a much higher peak,

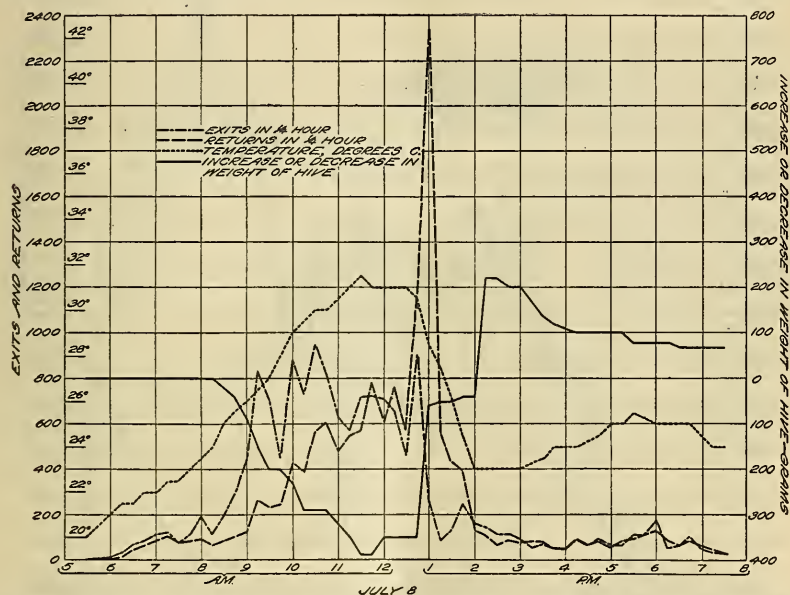


FIG. 5.—Flight, temperature, and hive-weight data for July 8, 1922, showing the effect of a storm (1.30–2.30 p. m.) on flights

relative to the normal trend of the curve, than would occur if nectar were abundant. On this day on the approach of the storm in the quarter hour ending at 1 p. m., three times as many bees returned as in the highest quarter-hourly return preceding the storm. A slight flight from the hive was apparent even through the light rain; but when at 2 p. m. the heavy rain began, the exits were reduced to about a sixth of those in the morning when the sun was shining brightly. Though the sun again shone brightly between 5 and 6 p. m., and the temperature was high, this low flight activity still persisted, indicating that in some way the bees seemed to know that any further effort would not be profitable, a behavior differing markedly from that of May 15, when the response to good weather by increased flight was immediate.

After such storms have cleared, it has been noted that a few of the returning bees show by the matted-down appearance of the hairs

of their bodies that they have been caught in the storm and after drying have flown back to the hive.

Showers, if they are of sufficient strength, produce the same effect as a severe storm, the periodicity of the curve corresponding exactly with the time of each shower. The effect of a shower of rain lasting only from 5 to 10 minutes is well illustrated by the records for May 19 (fig. 6), where a marked depression in the two curves is produced, the record of the weight of the hive showing a sudden increase during the shower, to be followed immediately by an equally abrupt decrease on the resumption of clear weather.

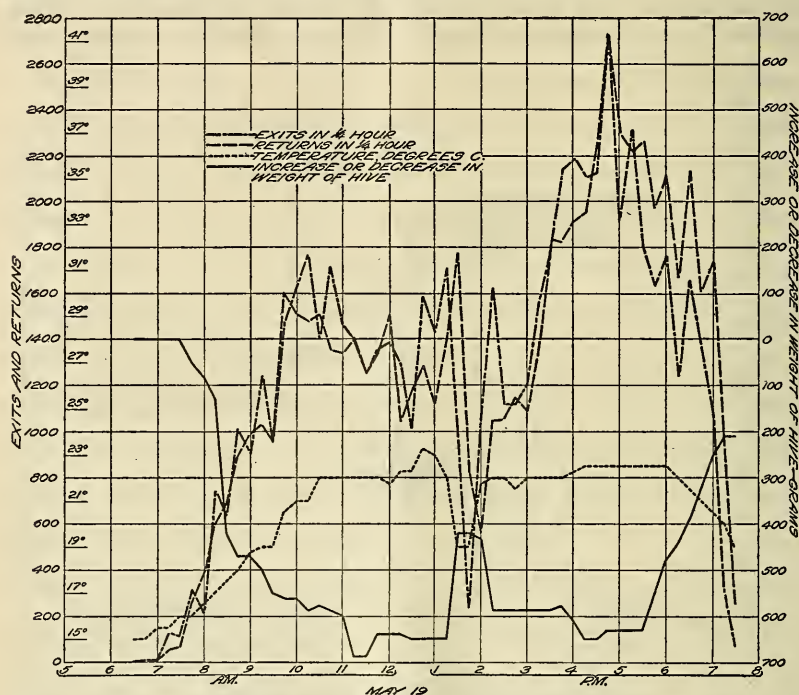


FIG. 6.—Flight, temperature, and hive-weight data for May 19, 1922, showing the effect of a shower of short duration on flights

The flight on an overcast day with some rain is illustrated by that of May 18 (fig. 7). The day set in dull with the following weather records:

Time	Weather conditions
6.00 to 9.15	Heavily overcast. At 6.30 a shower of short duration occurred.
9.15 to 10.15	Sprinkling.
10.15 to 11.00	Light rain.
11.00 to 11.45	Sprinkling.
11.45 to 12.15	Steady rain.
12.15 to 1.00	Heavy rain.
1.00 to 1.30	Light, steady rain.
1.30 to 2.00	Sprinkling.
2.00 to 2.15	It has stopped sprinkling.
2.15 to 2.45	Brighter, though still overcast, light frequently varying in intensity.
2.45 to 3.00	Becoming darker again.
3.00 to 3.15	Heavily overcast.

- 3.15 to 3.45 A few drops are falling.
 3.45 to 4.00 Sprinkling.
 4.00 to 4.30 Steady shower falling.
 4.30 to 4.45 Sun shining brightly, though shower continues.
 5.00 Rain has stopped, bright sunshine.
 5.15 Again clouding over.
 5.45 A few drops falling.
 6.00 The sun is shining through the clouds for brief intervals.

Although this day occurred between others of good honey flow, the hive showed a loss in weight. An apparent gain in early afternoon was due to water on the hive. Each period of rain caused a decrease in flight, the heavy rain about noon causing the greatest decrease. In each case the bees resumed flight promptly with the slightest improvement of weather conditions.

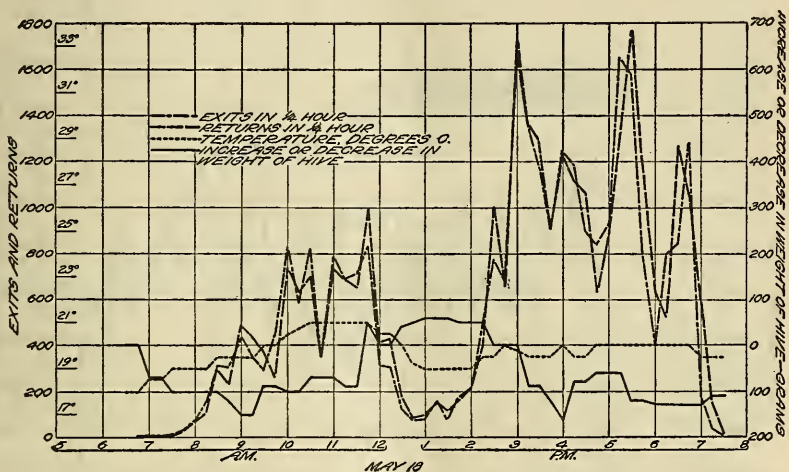


FIG. 7.—Flight, temperature, and hive-weight data for May 18, 1922, showing the effect on flight of an overcast day with occasional showers

THE EFFECT OF WIND

Unfortunately for a thorough study of the effect of wind, there were few days during the period of these observations when the wind was strong enough to affect the flight appreciably. The information is drawn from the records of only five days, and such statements as can be made on this subject are therefore made with some reservation.

April 11 was a windy day, with no substantial honey flow. The successive numbers of exits increased with the rise in temperature until 8.30 a. m. During this period the velocity of the wind was only 4 to 5 miles per hour. Between 8.30 and 9 a. m. the wind velocity reached 10 miles per hour and the flight dropped and continued low, while the velocity of the wind increased to 11 and 15 miles per hour. At 2 p. m. the velocity fell to 6 miles per hour and later to 4 miles, with the flight responding by an increase, which no other observed factors would explain.

This record might suggest that a velocity of 10 miles per hour is the minimum velocity appreciably affecting flight. However, this can not be the case, for on April 10 a play flight took place, when

the wind velocity was as high as 14 to 17 miles per hour. Again, on May 19 (fig. 6), a day when the morning's weight was all but regained at the end of the day, a wind of 9 to 10 miles per hour, from 8 a. m. to 4 p. m., apparently scarcely affected the flight, which was greater by 54 returns than on the following day when the wind velocity was only 1 to 4 miles per hour. On these two days the wind velocity was taken from an anemometer about 5 feet from the ground and about 20 feet from the hive.

The only other windy day of any consequence—June 22, a day in the dearth—during which from 9 a. m. to 6 p. m. the wind varied from 16 to 21 miles per hour shows a reduction of 28.53 per cent in

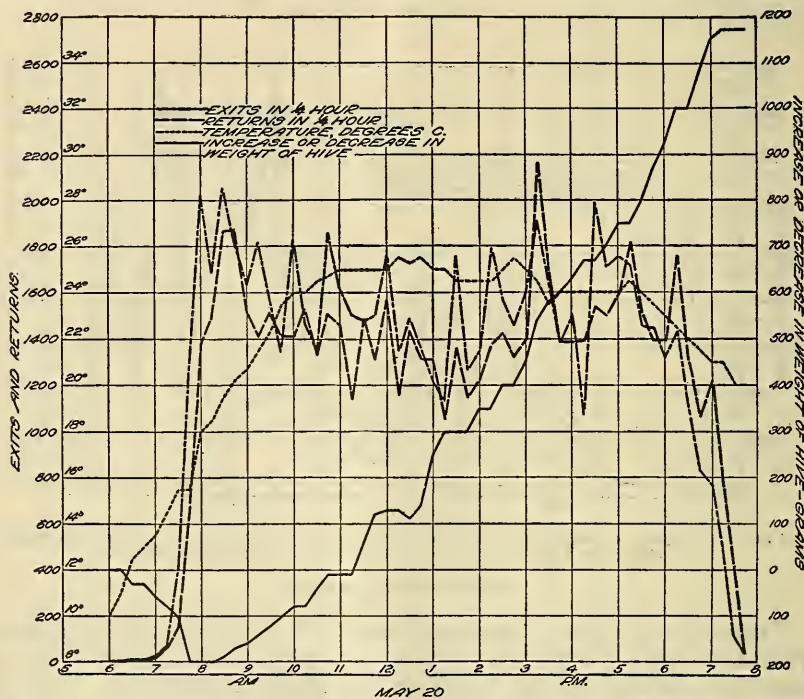


FIG. 8.—Flight, temperature, and hive-weight data for May 20, 1922, a day in a time of honey flow

the total day's flight, when compared with June 23, a day with little or no wind. The wind velocity on the former day is taken from the data obtained by the Weather Bureau in Washington at a higher elevation from the ground.

THE EFFECT OF TEMPERATURE

It is only when all the factors influencing flight but one are at least at an intensity favorable for flight, and this last factor is increasing in intensity toward this condition, that its minimum intensity can be determined. Any one factor can become the lagging factor at one time or another. In the early part of the season temperature is this factor more often than any other.

To present all the data from which the following conclusions on the effect of temperature have been reached would unduly increase the volume of this paper. Such as are essential have been inserted in the curves for the flights of May 15 (fig. 4), May 19 (fig. 6), May 20 (fig. 8), July 8 (fig. 5), July 10 (fig. 9), and July 12 (fig. 10); and these curves have been presented mainly to illustrate phases of behavior other than the responses of bees to temperature.

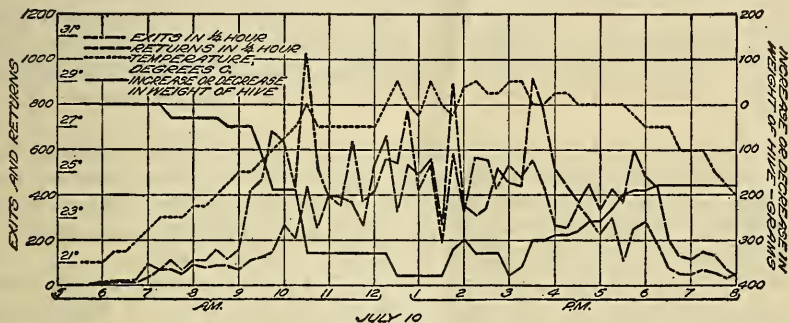


FIG. 9.—Flight, temperature, and hive-weight data for July 10, 1922, a day in a time of dearth

A study of the temperature at which flight commenced on each of the successive days of this investigation shows:

1. Under a particular set of conditions this temperature is uniformly within 2° to 3° C. of a certain definite temperature, which however, is not the same throughout the season. During April flight usually began between 12° and 14° C. (53.6° and 57.2° F.). In May the temperature at which the first bees came out was usually



FIG. 10.—Flight, temperature, and hive-weight data for July 12, 1922, a day in a time of dearth

from 14° to 16° C. (57.2° to 60.8° F.), with the main flight beginning at 16° or 18° C. (60.8° or 64.4° F.). In June and July the temperature at which flight commenced was very inconstant, varying between 13° C. (55.4° F.) and 27° C. (80.6° F.), being most frequently from 19° to 25° C. (66.2° to 77° F.), and showing that at this time of the year temperature is not often a factor in retarding the beginning of flight.

2. On dull, overcast days the bees usually do not begin their flight until the temperature has risen at least 2° C. (3.6° F.) higher than the usual temperature for beginning flight for that period. This was very marked in April, May, and the early part of June, but was not so obvious during the latter part of June and the month of July.

3. The internal condition of the colony is important in determining the temperature at which flight will begin. Colonies in the apiary that were stronger than the one under experimentation always commenced their flight at somewhat lower temperatures. The lowest temperature at which the flights from this colony began was on two days in April, when the temperature was as low as 10° C. (50° F.).

4. No marked difference in flight temperature between honey flow and dearth conditions in the same period can be found, and no conclusive evidence has been observed from these data that a heavy honey flow induces the bees to go out in large numbers at a temperature lower than they would if no nectar were available.

5. If from a lower temperature the thermometer rises rapidly to a condition suitable for flight, the temperature at which flight commences is usually 2° C. or more higher than if the temperature had risen slowly. In the first case, the flight curve usually shows a more gradual ascent to its peak; in the latter, a more rapid rise is observed, indicating, as might be expected, that the hive as a whole must absorb a certain amount of heat before the bees become active enough for a general flight.

6. A comparison of the temperature at which the flight begins its upward trend and that at which it begins its descent in the afternoon shows that, without exception, the temperature at which the bees begin to slacken their flight activities in the afternoon is higher than that at which they become active in the morning, the difference ranging from 1° to 9° C. This indicates that it is the waning light which accompanies the approach of sunset, rather than a fall in temperature at that time, that causes the decrease in flight.

7. A study of the seasonal flight curve (fig. 2) shows that a low morning temperature, by postponing the time at which flight commences, may reduce the total possible daily exits by as much as 50 or even 75 per cent. Days which appear to be similar in every other respect, but on which a variation in flight of from 10 to 25 per cent is noted, furnish records which show that this difference may be traced to lower temperatures in the early part of the day.

8. On some excessively hot days the flight curves remained low. Whether this behavior is due to the high temperature or to the dearth existing it is impossible to say.

THE EFFECT OF LIGHT

Since temperature and light intensity are so closely correlated, it is exceedingly difficult to differentiate the behavior produced by variations in either of these factors. In the study of the effect of light, a record was made of the degree of cloudiness each quarter of an hour while flight was occurring. Because of variations in the density, altitude, and position of the clouds, to say nothing of the

personal equation in the taking of such intangible data, this method was not wholly satisfactory, though useful for a broad interpretation. A better method would have been to supplement these data with an actual measurement of the light intensity by means of a photometer. Had this been done, when light is a lagging factor a more definite intensity would have been found marking the commencement of flight and on the approach of sunset the intensity at which the number of exits begins to fall would also prove to be rather definite. Whether these two intensities as affecting flight at the beginning and end of the day would be identical, or whether the evening intensity is lower or higher than the morning is a matter yet to be determined.

The flight curve typical of a bright, sunny day with all other factors at their most favorable intensity shows a sudden ascent to a point where the outgoing and incoming bees begin to balance in number, and continues more or less level till, at the end of the day's flight, the descent of the curve is as abrupt as was its commencement.

On dull days the ascent of the curve is more gradual, as is usual when any factor is not at an optimum.

Comparing the months of May and July, it is found that on the first day of May the sun rose at 5.03 and on the last day at 4.37 a. m. Although the flight commenced about 7 a. m. on most of the sunny days in this month, the first quarter of an hour having exits amounting to at least 400 bees ended at 7.45 or 8 a. m. Throughout July, on the other hand, when the sun rose about the same time (4.38 to 4.59 a. m.), on account of the high temperature prevailing the first bees were flying as early as 5.45 to 6 a. m. and yet the first quarter of an hour with as many as 400 exits usually did not occur until 8.15 to 8.45 a. m. Though the colony was weaker in July than in May, these facts reflect the nectar conditions prevailing rather than the effects of temperature or light.

THE HONEY FLOW

A survey of the flight activities of the season as a whole (fig. 2 or Table 1) shows that of all the external environmental factors which influence the magnitude of the flight occurring on any normal day, a heavy honey flow of nectar is the strongest. These flights during the honey flow (May 3 to May 28) were on the average three to four times as great as at any other period of the observations (see fig. 2). In order to follow in minute detail the variations in the flight which occur in the course of a day's activity, the number of bees departing and the number returning to the hive each quarter of an hour have been recorded, as well as the quarter-hourly change in the weight of the hive.

The flights typical of the honey flow are well illustrated by the records for May 20 (fig. 8) or May 15 (fig. 4), and those of a dearth are also well illustrated by the records of July 10 (fig. 9), July 12 (fig. 10), and May 19 (fig. 6), a day of dearth within the period of the honey flow. In general it is found that at the beginning of the day's flight the number of bees leaving each quarter of an hour becomes larger and larger, to be followed later by a corresponding increase, as on May 20 (fig. 8) or July 12 (fig. 10), in the number of bees returning. At the close of the day's flight the successive

numbers of outgoing bees decrease, followed later by a corresponding decrease in the number of returns until flight ceases for the day.

The characteristic differences typical of the flights during a honey flow and dearth are respectively :

1. During the honey flow, as on May 20 (fig. 8), there is a very steep ascent of the outgoing curve on the advent of the optimum conditions for flight, with a corresponding abrupt descent in the curve on the approach of sundown. In a dearth, as on May 19 (fig. 6) or July 12 (fig. 10), these ascents are more gradual. Instead of the peak of the flight being reached within three-quarters of an hour or an hour after the main flight to the field begins, as in the honey flow, it is not attained until about four or even five hours later.

2. In the honey flow the portion of the curve lying between the morning peak and the time when, at the close of flight, the number of exits begins to drop, approximates a horizontal straight line, showing that the rate of flight is fairly constant, there being almost as many bees departing as arriving. In the dearth, on the other hand, as on July 12 (fig. 10), this portion of the curve is not horizontal but tapers away gradually to zero, indicating that on the discovery of the dearth the bees conserve their energies by reduced activity.

3. The horizontal distance (indicating length of flight) between the curves representing the outgoing and incoming bees in a heavy honey flow is always shorter and sometimes very much shorter than it is in a dearth. This is specially apparent when in the morning the flights are on the increase and again in the evening when they are on the decrease. This distance, which is indicative of the average duration of each voyage, can not be followed precisely on a curve plotted in this manner. This will be dealt with separately in a discussion of the average duration of the trips (p. 26).

4. A study of the changes in weight of the hive, indicated in Figures 4 to 10, shows that as the successive number of departing bees increases the weight correspondingly decreases; then, again, as the number of nectar-laden returning bees increases the hive begins to regain its early morning weight. During the first days of the honey flow the time at which this regaining of the original weight occurs is well on in the afternoon or even at the end of the day. As nectar conditions improve, the time at which the original weight is regained comes earlier in the day. Then, as the honey flow wanes, this time again occurs toward the latter part of the day. In the dearth proper the drop in weight of the hive is considerable. This is due more to the long trips, with the majority of the flying force absent from the hive at one time, than to the small loads that they bring back. Since little or no nectar comes in, the morning weight is frequently never regained, a loss in weight being continually recorded for the entire day. This loss indicates the amount of stores consumed to maintain this flight activity in a main search for nectar, and to maintain other colony activity.

The amount of nectar gathered on any particular day depends not only upon the factors governing nectar secretion, but also on the factors governing the flights for that day. The secretion may be equally good on two selected days, but on account of a relatively adverse condition for flight of shorter or longer duration on one of these

days the gathering may not be so great. A comparison of the amounts of nectar gathered on certain days is not always absolutely indicative of the amount of nectar available to the bees on these particular days. This will be seen clearly from an inspection of Table 1, in which are tabulated the total number of returning bees on each day (except when the weight records were disturbed by rain), the daily increase in weight of the hive, and the minimum limits of the average load carried by each bee on these respective days. The average load as given in this table is obtained by dividing the day's gain in weight by the total number of returns for the day. Since consumption of stores, evaporation of excess water in the nectar, and other sources of loss in weight of the hive as a whole are going on throughout the day, it is evident that the average loads here computed are actually the minimum limits for the average loads carried. Other observers have noted that bees sometimes carry larger loads of nectar than have been indicated for the best day, judging by the total gain of the colony for the day (May 11, 24.1 milligrams), so that the figures given in Table 1 are evidently very conservative. Throughout the following discussion the expression "average load" refers to these minimum limits. On May 15 slightly less nectar (20 grams) was gathered than on May 16, yet the average load was greater by 1.2 milligrams. The total day's gain was minimized by a threatening storm which reduced the number of possible flights.

Again, on May 22 the load per bee is high (25.3 milligrams), yet the total day's gathering is less than on May 20, when the average load was 17.5 milligrams. This can be accounted for only by the fact that on May 22 some factors were influencing the flights and lengthening the average duration of each flight by about 9 minutes (Table 2), which would in turn reduce the total exits for the day and the amount of nectar gathered.

Without a knowledge of the number of flights which occur, a study of the daily gains on May 9 and 24 would indicate that May 24 was a day of heavier secretion, since more nectar was brought in on this day; but a comparison of the total returns and the average load per bee shows that the reverse was the case.

In general, Table 1 shows that although there is a close relation between the average load carried by each bee and the daily total, the amount of nectar gathered is not necessarily indicative of the quantity of nectar available to the bees. The average load per bee is the true indicant.

On six days only—one in April, three in May, one in June, and one in July—did the frequency of the flights drop during the hours 12 m. to 2 p. m., as would be required by the weight curve described by Dufour (1) as typical of the spring conditions. On these days the drop did not last more than half an hour, and varied in magnitude from 15 to 40 per cent of the average number of exits or returns during the main flight for the day.

THE EFFECT OF HEAVY FLIGHT NEAR BY

Another colony about 36 feet from the one under experimentation was, on May 11, at 2.30 p. m., much disturbed by manipulation, so that the air in the vicinity was full of flying bees, almost as many

as when a swarm is on the wing. When the curve for this day's record was plotted, an unusual peak, about 40 per cent higher than the normal trend of the curve, was noticeable at this time on both the ingoing and the outgoing curves. Although other peaks occur at different times, usually only on a single curve at one time, none was so marked as this particular one. If this peak was actually a response to this disturbance in the neighboring colony, it is interesting to speculate as to the method of conveyance of the information to the bees within the experimental colony. This question suggests another use for these instruments, namely, a study of the reaction of bees to odor, sound, and other external stimuli.

THE AVERAGE DURATION OF TRIPS

A study of the factors which influence the length of time the bees are absent from the hive on each foraging trip is a distinct problem in itself. The amount of nectar available in the flowers, the position and nature of the nectaries, and the distance which the bees must travel to obtain this nectar are the chief factors which govern the average duration of the voyages; therefore, an intimate knowledge of this duration and its variations is of importance in a study of nectar secretion, especially with reference to the time of day when the maximum secretion occurs. At present it is possible to give only a limited selection of data from different parts of the season to show the daily and seasonal variations in the duration of the trips which actually occurred in this experiment.

A simple graphic representation of the average duration of the trips and their variations in the course of a day is obtained by plotting the progressive totals of all the bees which have left the hive and of all those that have returned up to the time of each successive reading from the cyclometers. The plotting of the exits gives a continually ascending curve to the end of the day's flight. The plotting of the returns gives a curve which follows the first curve in time, as determined by the average duration of each trip for that period of the day's flight. The horizontal distance between the two curves represents the average time the bees spend in the field. The vertical distance between the two curves at any time of the day represents the number of bees in the field at that time.

If we suppose a purely hypothetical case, in which a constant number of bees leave the hive and return within a certain definite interval of time throughout the day, two parallel straight lines, representing the exits and returns, would be obtained when plotted as described above. By comparing two similar triangles on such a diagram it is found that the ratio of the number of bees (n) which return in a given interval of time (t), is to this time (t) as the number of bees in the field (f) is to the average duration of the trip (x); that is, $n:t::f:x$, or $x = \frac{tf}{n}$. Turning now, for example,

to Table 3 (May 15, fig. 4) and Table 4 (July 10, fig. 9) it is found that the number of bees in the field increases at the beginning of the day and diminishes as the day closes. Between these two periods of the day there is a period during which the total number of bees in the field at any particular time is reasonably near a constant num-

ber. For this period of the day it may be assumed,³ for the purpose of estimating the duration of flight, that the two lines are parallel and that the above formula is applicable. To reduce the experimental error arising from this assumption, a period of flight is selected when the number of bees in the field at each reading in this period is known to be very near a constant number. The average of the number of bees in the field at each of the readings in this period is taken as the constant number (f) in the above formula. The number n may be taken from either the outgoing or the incoming totals, thus giving two answers for the duration of flight which may be used as a check on each other.

This method shows that on any day when the number of bees in the field is large it naturally follows that the flight is long; or, conversely, whenever the duration of each trip is short the number of bees in the field is relatively small. (Compare Tables 3 and 4.)

Care must be exercised in the selection of the data to be used in the determination of the average duration of each voyage, for if there has been a large loss in the number of bees which went to the field, the figures would at first glance suggest that the number of bees in the field, instead of remaining constant, is continually increasing, thus giving a larger figure for the average duration of each trip.

The data used for the determination of the average duration of each trip have been arranged (Table 2) to show the figures used in the calculations for each of the days given.

The probable error of the average was determined according to Bessel's formula, $0.6745\sqrt{\frac{\sum d^2}{n(n-1)}}$, and shows the precision of the

assumed constant number of bees in the field for each of the days given. To facilitate comparisons the probable error of the average has also been expressed as a percentage of the average.

Since there is a direct ratio between the average duration of the voyages and the average number of bees in the field during the period under consideration, it naturally follows that the probable percentage error of the average duration of the voyages, given in the last two columns of Table 2, is liable to the same probable percentage error as the average number of bees in the field. The remainder of the table is self-explanatory.

³ The straight line method has been applied to the data for May 15, July 9, and July 10, following the general formula—

$$(I) \quad \sum n + \sum x(m) = \sum y$$

$$(II) \quad \sum x(n) + \sum x^2(m) = \sum xy,$$

solving for m and n and substituting in $y = n + mx$, to determine the two points which fix the straight line sought.

For May 15, the straight line representing exits begins at number 4,501 and ends at 36,883, and gives 15.27 minutes as the average duration of the trips; the straight line representing returns begins at 3,133 and ends at 35,111, and gives 15.46 minutes as the average duration of the trips. For July 9 the exit numbers are 6,486 and 17,908, and the resulting average duration of trips 93.78 minutes; the numbers for the returns are 2,742 and 14,510, and the average duration of trips 91.20 minutes. For July 10 the exit numbers are 5,114 and 14,339, and the average duration of trips 102.13 minutes; the numbers for the returns 1,965 and 10,876, and the average duration of trips 105.74 minutes.

This method shows that the lines for the three days diverge somewhat as the time progresses. The average duration of the trips calculated on these lines differs so slightly from the figures obtained by the former method (see Table 2) that for the purposes of this paper, where no close comparisons in the average duration of the voyages is attempted, the formula $x = \frac{t}{n}$ derived above has been applied directly to the original data in the compilation of Table 2.

It will be noted that the average duration of the voyages was determined with a probable error ranging from less than one-half of 1 per cent to about 7 per cent, the average probable error being 2.45 per cent.

The number of days in the honey flow on which the average duration of the voyages could be determined with full confidence in the figures was small, owing not only to the fact that the honey flow in 1922 was short but also to the fact that it occurred very early in the season, when relatively more difficulties in connection with the apparatus had yet to be overcome. With changing weather conditions the duration of the voyages can be determined more conveniently by the graphic method, which, although not so accurate, is correct to about 3 minutes for the scale used in studying the data.

A survey of a few days (Table 2) shows that the average duration of the voyages varies considerably. The shortest average flight over a considerable period of time is that which occurred on April 20, 8.92 minutes, and the longest that of July 10, 103.92 minutes. Every gradation between these limits occurred. It will be noted that during the dearth of July the average duration of each flight is much longer than during the honey flow; and yet there are days in July when the duration corresponds very closely with such honey flow days as May 8 and 9.

It will be noted also that the duration of the voyages on May 8 and 9 was from two to three times as long as it was on May 15 and 17, and yet all four days (Table 1) were days of fairly good to good honey flow. This great difference can be attributed only to the nature and distribution of the honey plants. On May 8 and 9 the bees are working on the black locust (*Robinia pseudacacia*) entirely. The tuliptree (*Liriodendron tulipifera*) was not yet secreting nectar. On the 15th and 17th only the tuliptree was secreting, the black-locust blooms having been destroyed by a heavy rain on the 14th. The distribution of the trees of these two species in the immediate vicinity of the hive shows roughly that the black-locust trees most accessible are on the average about three times as far away as the nearest available tuliptrees. The structure of the flower of the black locust undoubtedly also contributes to lengthening the average duration of the voyages by requiring a greater exertion from the bee in securing its load of nectar.

The data for May 15, June 6, and July 25 (Table 2) show that the duration of the flights may sometimes vary considerably within the same day. Under uniform conditions, however, it is usually very constant for the greater part of the day's flight.

Graphs (figs. 11, 12, and 13) have been drawn to show in greater detail these variations in the duration of the trips for May 15, a day of good honey flow from tuliptree; for July 10, a day in the dearth; and for May 9, a honey-flow day with locust secretion, with flights of intermediate length. Owing to the heavy flight which occurred on May 15, it has been necessary to cut the graph into three sections in order to draw it to the same scale as the graph for July 10. These sections should be joined so as to give a continually ascending curve such as is shown in Figure 12 for July 10. These curves show that at the commencement of flight the duration of the trips is relatively short, soon to be followed by the balanced

condition previously described, when the outgoing bees equal the returning bees in number. Again, as flight closes, a considerable shortening of the duration of the trips is shown. On May 15 (fig. 11), at 3.30 p. m., the two curves, representing the accumulated totals of bees emerging and bees returning, come together, to diverge immediately to a resumption of the previous condition of parallelism. This convergence with an immediate divergence was occasioned by a threatening storm, illustrated in a previous curve (fig. 4), which sent all the bees in the field back to the hive and neces-

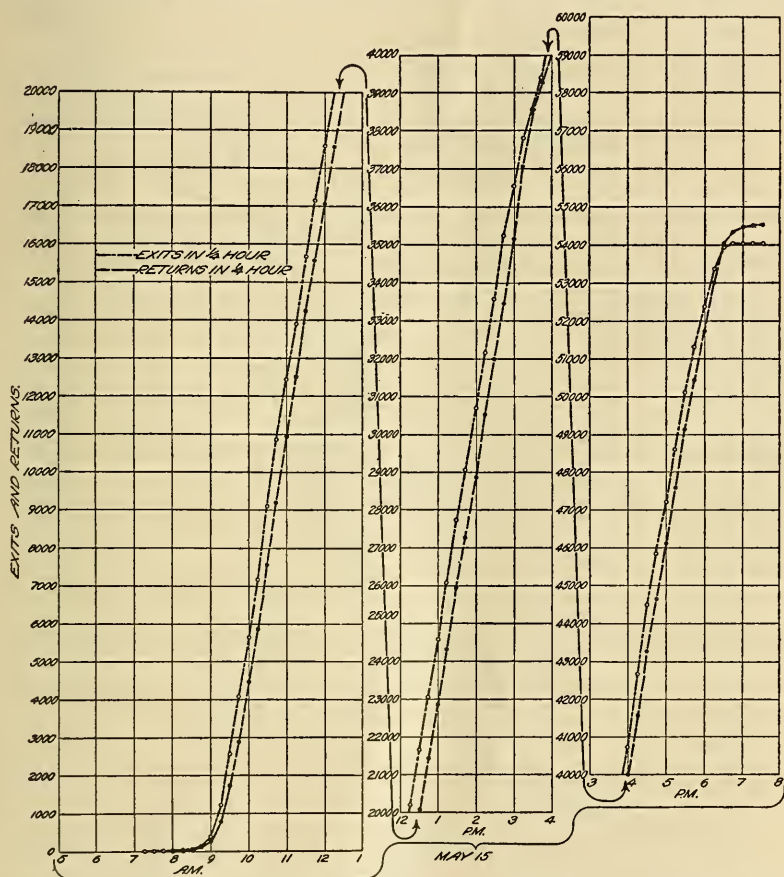


FIG. 11.—Graph representing flight data for May 15, 1922, a day of good flow of tuliptree honey

sitated an abrupt shortening of the duration of the voyage. At the end of the day the incoming curve, instead of ending below the outgoing curve, crosses it, the vertical distance between the ends of the two curves representing the accumulated experimental error for this day, when 467 more returns than exits were registered. This error has naturally tended to reduce the distance between the two curves, making the apparent duration of the voyages shorter than the real duration. To obtain some idea of the magnitude of the error produced in the determination of the duration of the trips in the period

from 4.15 to 5.15 p. m., the generous assumption may be made that all this error accumulated between 4 p. m. and 7.30 p. m. Applying a correction under this assumption to the number of bees in the field and the returns for this period, it is found on calculation that the duration of the voyage has been increased by 0.39 minute, still showing that the average duration of the flight has been reduced after the occurrence of the threatening storm. This error, however, should

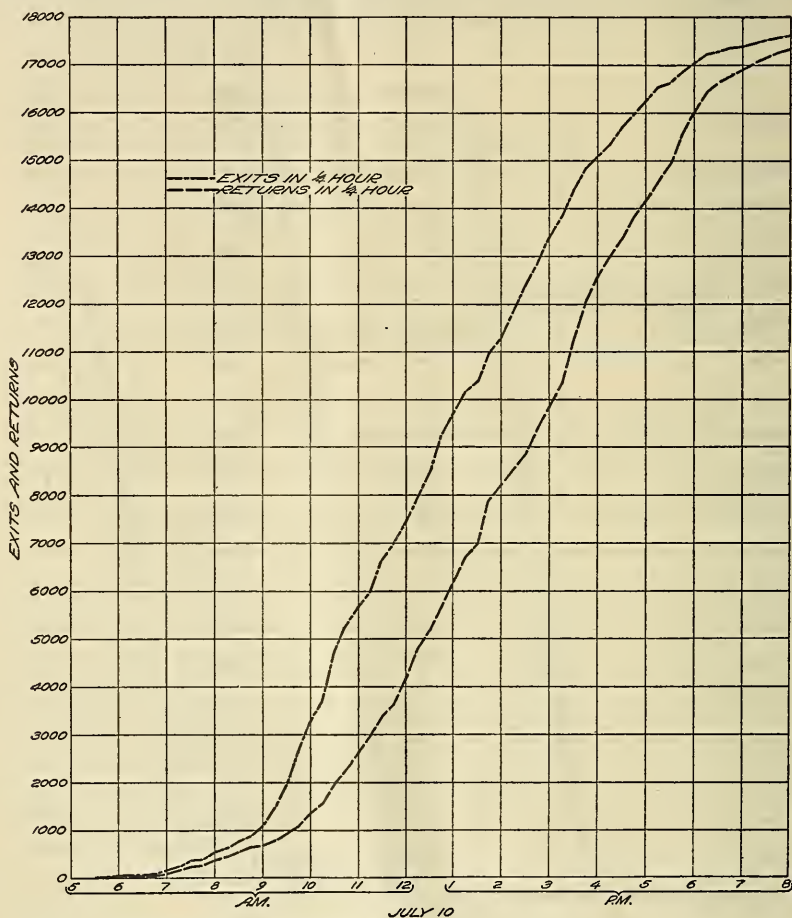


FIG. 12.—Graph representing flight data for July 10, 1922, a day of honey dearth

properly have been distributed over the whole day, so that its magnitude was actually much below the above figure.

In attempting to determine what factors are involved in this reduction in the duration of the trips, three things are suggested: (1) That the lower temperature prevailing after the storm stimulated the bees directly; (2) that the lower temperature and the conditions during and after the storm stimulated a relatively heavier secretion, enabling the bees to load more rapidly; or, perhaps, (3) that since fewer bees were visiting the flowers during the threatening storm, relatively more nectar was available to them on

the resumption of optimum conditions for flight. The third factor seems the most probable.

July 10 is a good example of a day of great dearth with long flights (fig. 12). The average duration of the voyages in the period from 10.45 a. m. to 3.30 p. m. on this day was 1 hour and 43 minutes. During a portion of this period (from 12.36 to 1.15 p. m.) all the bees (about 1,400) which set out from the hive were absent for as long an interval as 1 hour and 54 minutes. The curve shows a gradual lengthening of the duration of the trips from 15 to 36

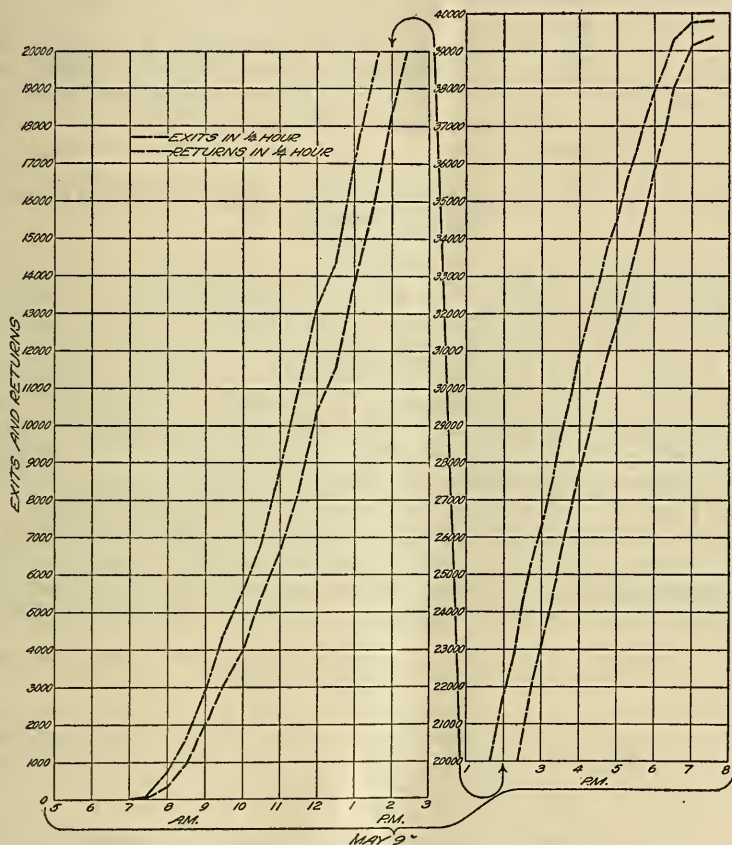


FIG. 13.—Graph representing flight data for May 9, 1922, a day of good flow of locust honey

minutes between 7 and 8.45 a. m., followed by rather sudden lengthening of the trips from 36 minutes to 106 minutes between 8.45 and 10.45 a. m., which is the beginning of the period of approximate flight equilibrium mentioned above. At the end of the day, as the flight activity comes to a close, a gradual shortening of the duration of the trips is noted. A comparison of the evening shortening with the morning lengthening in the duration of the voyages shows that the lengthening in the morning is somewhat sudden, whereas the shortening in the evening is more gradual. These characteristics were noted on all the days studied. The

necessity of a shortening of the voyages as dusk approaches is apparent, but the cause of the short voyages at the beginning of the day's flight is problematical. It may be that these short trips in the dearth are those made by the water carriers.

The flights which occurred on May 9 (fig. 13) when locust honey was available, were intermediate between those given above, their average duration in the period of equilibrium being 42 minutes. The bees were obliged to travel a considerable distance. The details of the variation for this day are easily interpreted from the figure, and need not be explained in full. The method of interpretation is the same as for the examples given above.

These data also indicate that when conditions for a maximum secretion of nectar occur, enabling the bees to gather their loads rapidly and return quickly to the hive, there are relatively more bees within the hive. The significance of this fact with reference to swarming is apparent.

A LIMIT TO THE NUMBER OF TRIPS AND THE TIME SPENT WITHIN THE HIVE

To determine the number of trips which the bees of a colony of honeybees make in the course of any particular day, it is necessary to know the total number of exits (or returns) for the day and the total number of bees which are participating in the flight on this day. Owing to the limited time available for this investigation, no attempt was made to manipulate the colony periodically so as to take a census of the field bees. With the figures available, however, a lower limit to the number of bees participating in the flight is given by the average number of bees in the field, giving in turn an upper limit to the number of trips each bee could make. For example, May 15 (9.45 to 3) the average number in the field is 1,567, so that during this period each bee could not make as many as $32,492 \div 1,567 = 20.74$ trips, for to maintain this rate these 1,567 bees would have to go in and then out of the hive immediately.

TABLE 4.—*Record of exits and returns, total and per quarter hour, and of bees in the field, July 10, 1922*

Time	Total exits	Total returns	Bees in field	Exits in one-fourth hour	Returns in one-fourth hour	Time	Total exits	Total returns	Bees in field	Exits in one-fourth hour	Returns in one-fourth hour
			<i>Number</i>	<i>Number</i>	<i>Number</i>				<i>Number</i>	<i>Number</i>	<i>Number</i>
5.30	0	0	0	0	0	10.15	3,674	1,513	2,161	434	203
5.45	4	2	2	4	2	10.30	4,699	1,946	2,753	1,025	433
6.00	18	11	7	14	9	10.45	5,212	2,201	3,011	513	255
6.15	32	19	13	14	8	11.00	5,610	2,595	3,015	398	394
6.30	46	31	15	14	12	11.15	5,265	2,981	2,984	355	386
6.45	63	41	22	17	10	11.30	6,600	3,249	3,251	655	368
7.00	160	73	87	97	32	11.45	6,971	3,613	3,358	371	264
7.15	225	147	78	65	74	12.00	7,381	4,133	3,248	410	520
7.30	332	219	113	107	72	12.15	7,930	4,792	3,138	549	659
7.45	398	269	129	66	50	12.30	8,469	5,117	3,352	539	325
8.00	503	360	143	105	91	12.45	9,242	5,646	3,596	773	529
8.15	612	438	174	109	78	1.00	9,662	6,134	3,528	420	488
8.30	770	525	245	158	87	1.15	10,197	6,692	3,505	535	558
8.45	887	609	278	117	84	1.30	10,382	6,955	3,427	185	263
9.00	1,044	675	369	157	66	1.45	10,965	7,848	3,117	583	893
9.15	1,461	785	676	417	110	2.00	11,290	8,197	3,093	325	349
9.30	1,923	907	1,016	462	122	2.15	11,851	8,509	3,342	561	312
9.45	2,604	1,050	1,554	681	143	2.30	12,405	8,849	3,556	554	340
10.00	3,240	1,310	1,930	636	260	2.45	12,828	9,366	3,462	423	517

TABLE 4.—*Record of exits and returns, total and per quarter hour, etc.—Con.*

Time	Total exits	Total returns	Bees in field	Exits in one- fourth hour	Returns in one- fourth hour	Time	Total exits	Total returns	Bees in field	Exits in one- fourth hour	Returns in one- fourth hour
			<i>Number</i>	<i>Number</i>	<i>Number</i>				<i>Number</i>	<i>Number</i>	<i>Number</i>
3. 00	13, 357	9, 816	3, 541	529	450	5. 45	16, 861	15, 538	1, 323	252	594
3. 15	13, 831	10, 354	3, 477	474	538	6. 00	17, 040	16, 022	1, 018	179	484
3. 30	14, 378	11, 265	3, 113	547	911	6. 15	17, 225	16, 451	774	185	429
3. 45	14, 820	12, 051	2, 769	442	786	6. 30	17, 298	16, 654	644	73	203
4. 00	15, 082	12, 570	2, 512	262	519	6. 45	17, 350	16, 788	562	52	134
4. 15	15, 334	13, 007	2, 327	252	437	7. 00	17, 394	16, 907	487	44	119
4. 30	15, 688	13, 370	2, 318	354	363	7. 15	17, 463	17, 056	407	69	149
4. 45	15, 986	13, 812	2, 174	298	442	7. 30	17, 533	17, 191	342	70	135
5. 00	16, 212	14, 149	2, 063	226	337	7. 45	17, 584	17, 266	318	51	75
5. 15	16, 508	14, 574	1, 934	296	425	8. 00	17, 619	17, 305	314	35	39
5. 30	16, 609	14, 944	1, 665	101	370						

On any day when the conditions governing flight are fairly uniform throughout the course of the day, it has been found, as has been previously explained (p. 26), that sooner or later the flights approach a state of equilibrium (Tables 3 and 4), the group of bees in the field remaining almost constant, the flow of bees to this group being balanced by the flow from it. The magnitude of the group of bees participating in flight, but remaining in the hive, and which will eventually reissue therefrom, must therefore also remain approximately constant. Then, again, just as there is a direct ratio between the number of bees in the field and the time they are spending in the field, so must there also be a direct ratio between the number of bees in the hive taking part in the flight and the time they spend in the hive between the trips during the period of equilibrium.

If we assume that on May 15 there were as many bees in the hive participating in the flight as there were bees in the field, the bees were spending as much time in the hive as out of it. The inferior limit to the number of bees participating in the flight on this day would then be 3,134 bees, and the maximum limit to the number of trips would be 10.27. This figure 3,134 seems to be a relatively small fraction of the total colony, which at this time must have consisted of some 5 pounds of bees (about 25,000). These figures seem to suggest, therefore, that even in a strong honey flow the bees spend more time in the hive between the voyages than they do on the voyage itself.

THE DEATH RATE OF THE COLONY

Since the mechanism of the gates prevented the bees from carrying out their dead, these collected behind the incoming gates, where they were counted and removed every time the gates were detached for cleaning. This meant that at certain periods they were counted every day and at others once in four or five days, depending upon the condition of the instruments. On only one occasion did the count ever exceed 100 bees. The total number of bees which died in the hive while the instruments were attached was 1,060. This is 1.63 per cent of the total number of bees (65,178) recorded lost from all causes. In handling the apparatus the writer has gained the rather indefinite impression that as a rule there is a greater error on the outgoing gates than on the incoming. If this is true, the actual percentage of deaths in the hive is slightly above this figure.

The records for 89 days, which have been chosen as representative of the data obtained, show that of the bees which left the hive (2,434,666), 3.16 per cent did not return. If the assumption is made that the errors in the counts of exits and entrances balance each other, this would mean, since every exit represents a trip by a bee, that one bee dies after every 31.65 exits have occurred, or that each bee makes 31.65 trips before death overtakes it in the field.

It is generally accepted that the mortality of honeybees is in proportion to the amount of work which they do. It is also evident that during the night, when flights do not occur, all deaths will take place within the hive, and during the active season there is usually a period of 10 hours daily when there are no flights. If, therefore, about 98 per cent of the deaths from the colony occur in the field, this indicates that most of the deaths occur during the approximately 14 hours of flight. These data suggest that the energy expended by the bees in flight and in activities outside the hive greatly exceeds that expended within the hive. This conclusion is to be anticipated from the enormous amount of energy which must be expended in flight. Assuming (1) that a field bee is away from the hive one-half of the flying hours, (2) that a death rate of 2 per cent occurs within the hive, and (3) that there is a 14-hour period of flight for the day, the chance of a bee dying outside the hive during any given hour of the period of flight is about 120 times as great as the chance that death shall occur within the hive. This at least suggests that for any given instant the expenditure of energy on flight or away from the hive is about 120 times as great as that expended by a single bee within the hive.

THE BEHAVIOR OF THE BEES TO THE INSTRUMENTS

In the initial stages of the experiment, although about 2,000 bees passed satisfactorily through the experimental model, the reaction of the colony as a whole to the complete set of instruments was entirely problematical. The success or failure of the experiment, therefore, depended upon this reaction. The plan of placing the outgoing gates above the incoming ones, so that the actual entrance apertures were only about 2 inches below the exit apertures, proved very satisfactory, only an occasional bee attempting to enter the hive by an outgoing gate.

Considering the tunnel of the contact device as a hole in the wall of the hive which drops a distance equal to twice the height of a bee while the latter passes through it, the delay produced by these instruments is negligible and the only abnormality introduced is the jar of the tunnel meeting the lower stop. Owing to the fact that any hesitancy of a bee in walking out of the tunnel prevents another from using this aperture, a net delay on all the apertures ensues. The return movement of the tunnel to receive the next bee is a minor source of delay when compared with that produced by the hesitancy shown by some of the bees in selecting the aperture by which they finally enter. Probably this hesitancy on the outgoing gates is not so marked. It has been impossible to determine the actual delay produced. On seeing the rapidity shown on certain occasions by some of the bees when leaving the outgoing gates, one would not hesitate to state that these bees left the hive as rapidly as they do

normally. The hesitancy mentioned above was greater when there were fewer bees on the alighting board, as, for example, before or after the main flight of the day or on dull, overcast days. On leaving the tunnel some of the bees would stop to fan their wings, and many others might simply clean their antennae or perform some minor movement and then fly away, as if everything were normal.

At the beginning of the experiment the binding posts on the instruments were exposed. Bees in walking over these could short-circuit the current, getting an electric shock to which they reacted in an interesting manner. They did not cause a record to be made by the cyclometers when this occurred. The excitement of the first bee to get a shock soon drew others to the scene of the phenomenon. Some would approach the binding posts with apparent caution and on getting a shock would retreat and then return to repeat the operation again and again, until finally a few superinfuriated ones went to war against this invisible enemy by attempting to deposit their darts in the brass work. The stings usually found a final lodging place in the rubber insulation on the wires. These efforts being of no avail, other bees proceeded to propolize the instruments, thus perhaps utilizing for the first time the insulating value of propolis. This abnormal behavior was discontinued when the binding posts were covered with cotton wool.

The light penetrating the outgoing gates through the glass windows attracted the bees so strongly that two bees sometimes attempted to enter the tunnel at one time, thus retarding or preventing its drop and their egress from the hive. By darkening the glass, thus reducing the intensity of the light, a satisfactory action was brought about, which increased the former capacity of the instruments by about four times. This behavior was entirely contrary to all expectations, for in the design of the instruments an attempt was made to get the maximum of light to enter the outgoing tunnels. In actual practice, to promote a correct action of the instruments, this light was almost completely shut out by the black paint placed on the glass. It is interesting to note that the bees used the tunnels with no apparent hesitation, although the light intensity was far below normal.

During the hot weather following the main honey flow a large number of bees, instead of returning to the entrance apertures as normally, collected on the platform of the scales under the hive. This occurred especially about midday and in the early afternoon and they would remain in this place all night, apparently held there by the hive odor which emanated from the ventilator in the bottom of the hive about 14 inches directly above them. With the exception of the above incidents, all of which were eventually avoided, at no time, so far as could be determined, did these instruments produce any abnormality in the behavior of the colony.

The highest rate at which the instruments ever worked was in one quarter of an hour preceding a storm, when each ingoing gate admitted in these 15 consecutive minutes an average of 14 bees a minute.

CONCLUSIONS

A satisfactory device for counting bees as they journey to and from the hive would open up a new field of apicultural research. In addition to throwing light on many interesting questions, its most prac-

tical application would perhaps be in a study of nectar secretion, as it affords a measure of the variations in flight and in the duration and number of trips which the bees make, as well as their average daily load, facts which are to a large degree a reflection of the nectar conditions in the field.

This study demonstrates the feasibility of obtaining data on problems pertaining to the flight of bees by means of an automatic recording mechanism. As far as can be ascertained, the mechanical principles on which the design was made are in general correct. Much work, however, on further details is desirable.

Owing to factors incidental to any new and untried mechanism, a variable experimental error was introduced which as far as can be determined for any day varied from 0.08 per cent to as much as 27.81 per cent. The magnitude of this error, though prohibitive for certain phases of the study, was not entirely so for others, and by a selection of those days on which it was obviously at a minimum, information may be obtained which is practically as valuable as if no error were incurred.

A survey of the total daily exits and returns for the period of the observations shows that a factor or group of factors can reduce the total number of possible exits by an amount varying from total prohibition of flight to a fraction of 1 per cent. A threatening storm, for instance, of but one hour's duration, reduced the possible flight on one day in the honey flow by 7.41 to 9.67 per cent.

Comparatively few data have been obtained on the effect of wind on the flights. On one day, however, a wind velocity of 16 to 21 miles per hour during the hours 9 a. m. to 6 p. m. reduced the possible maximum flight by 28.53 per cent.

Under a particular set of conditions the temperature at which the day's flight commences is uniformly near a certain definite temperature, but this definite temperature is not always the same. In April it was from 12° to 14° C. and in May from 16° to 18° C. On dull days this temperature was usually 2° higher. The internal conditions of the colony govern this temperature somewhat, a strong colony commencing flight at a lower temperature than does a weak one.

There is a considerable variation in the hour and temperature at which the peak of the flight in the honey flow occurs. No conclusive evidence has been obtained that under similar conditions a good honey flow induces the bees to go out in large numbers at a lower temperature than they would if no nectar were available. The temperature at which the flights in the evening begin to slacken was without exception higher by from 1° to 9° C. than the temperature at which flight began in the morning. Days which appear to be similar in every respect but which show a variation of as much as from 10 to 25 per cent in their total flights are found to differ on account of a lower temperature in the early part of the day.

Under honey-flow conditions the total exits proved to be three to four times as great as they were at any other time of the investigation.

A typical flight, where all conditions are fairly uniform and favorable throughout the day, is a gradual to rapid increase in the successive numbers of bees which set out from the hive, to be followed by a condition of equilibrium in which the outgoing numbers

are balanced by almost equal incoming numbers. Under these conditions it was found that the number of bees in the field remained nearly constant.

Under honey-flow conditions the main flight to the field usually occurred some three to four hours earlier than in the dearth.

From the graphs representing the progressive totals of outgoing and incoming bees the average duration of each flight at any period of the day can readily be determined. During the main flight for the day, when usually a balanced condition of flight is maintained, these graphs are represented by two almost parallel straight lines. The morning and evening flights are very much shorter than those that take place in the main period of the day's flight, a variation of as much as from 15 minutes to 1 hour and 43 minutes occurring in one day. Taking all the days for which the average duration of the trips was determined, it is found that this duration varies from 8 minutes to as much as 1 hour and 54 minutes. In the honey flow the trips are much shorter than they are in a dearth.

Although the colony was not manipulated periodically so as to take a census of the field bees, the figures available seem to show that even in a heavy honey flow the bees spend more time in the hive between trips than they do on the trip itself.

By knowing the amount of nectar gathered on any day and the total number of bees which return, the minimum weight of the average load carried by each bee can be estimated. The highest minimum average load obtained was on May 22, when 44,597 bees averaged 25.3 milligrams each. Although there is a close relation between the amount of nectar gathered on any day and the amount of nectar available to the bees, this relation is not absolute. The average load per bee is the true indicant of the available nectar.

Assuming that the errors on the outgoing and incoming gates balanced each other, the records for 89 days show that of the 2,434,666 bees which left the hive 3.16 per cent did not return. This would mean that on an average a bee makes about 31.65 trips before death overtakes it.

Of the 65,178 bees lost from all causes 1.63 per cent died in the hive.

Except for certain difficulties which were eventually overcome, at no time during the three and one-half months of this investigation did these instruments produce any discernible abnormality in the general behavior of the colony. The highest rate at which the gates were ever worked was during a quarter of an hour preceding a storm, when each incoming gate admitted in these 15 consecutive minutes an average of 14 bees per minute.

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EMULSIONS OF WORMSEED OIL AND OF CARBON DISULFIDE FOR DESTROYING LARVAE OF THE JAPANESE BEETLE IN THE ROOTS OF PERENNIAL PLANTS¹

By B. R. LEACH, *Associate Entomologist*, and J. P. JOHNSON, *Junior Entomologist, Fruit Insect Investigations, Bureau of Entomology*

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THE PLANTS CONCERNED

Japanese iris (*Iris kaempferi*),² peonies (*Paeonia* spp.), and perennial phlox (*Phlox* spp.) are all extensively grown in and near the area infested by the Japanese beetle, *Popillia japonica* Newm. The acreage of these crops in nurseries growing miscellaneous perennial stock is considerable, and there are also nurseries of considerable size specializing in iris and peonies.

These three plant species are essentially different from each other in root structure. The roots of Japanese iris (fig. 1) are an impenetrable mass of coarse fibers interspersed with small quantities of soil and emanating from a hard, thick rootstock or crown. Larvæ of the Japanese beetle are found in this mass of roots and soil close up to the crown, and can be discovered and removed only by cutting, which is an obviously impractical method. The roots of perennial phlox, while coarse and heavy, are not matted to any great extent except when the soil is wet at the time of digging in November, but this condition prevails in two out of every three years in New Jersey and it is then difficult to remove any larvæ present except by washing. This operation appreciably injures the roots. In the case of the peony, the root structure is tuberous with many cavities mostly formed underground by the flower stems of the previous

¹ The writers are indebted for assistance rendered by J. W. Thomson and W. E. Fleming, investigators, New Jersey State Department of Agriculture.

² It is fairly probable that the Japanese beetle entered the United States in the larval form in the roots of iris from Japan.

year's growth. These cavities fill up with soil (fig. 2) and frequently afford shelter to larvæ of the beetle. The larvæ can be detected and removed only by cutting, which frequently ruins the plant.

It has been found impossible to remove all the larvæ from these plants by such ordinary expedients as shaking or washing. In 1920 and 1921 only a portion of these crops was marketed, since no method was known whereby all the larvæ present in the roots of the plants could be killed without injury to the plants themselves. Under these circumstances the writers undertook a study of this problem in an effort to discover a solution in which the plants could be dipped without injury to them for the purpose of killing any larvæ present in their roots.

PRELIMINARY WORK

During 1920 and 1921 the writers conducted an extensive series of tests to determine the effect of various compounds upon the larvæ of the Japanese beetle and upon the roots of plants. The experimental procedure in the case of each compound was the same; larvæ were dipped for varying periods of time in filtered solutions of the compound under investigation and the mortality of the larvæ determined; potted plants, the soil of which was infested with larvæ, were *watered* with the filtered solutions and the larval mortality and the effect of the compound upon the plant were observed.

A partial list of the materials tested in this connection is given in Table 1. They include inorganic salts, alkaloids, essential oils, and representative compounds of the various organic groups. It will be observed that oil of wormseed not only controlled the larva but checked the plant only to a slight extent; carbon disulfide was somewhat more injurious to the plant. The other compounds were either innocuous to the larvæ or killed the plants. In view of these results and in consideration of the great amount of experimental work required to test out each compound thoroughly the writers decided to limit the research to wormseed oil and carbon disulfide.

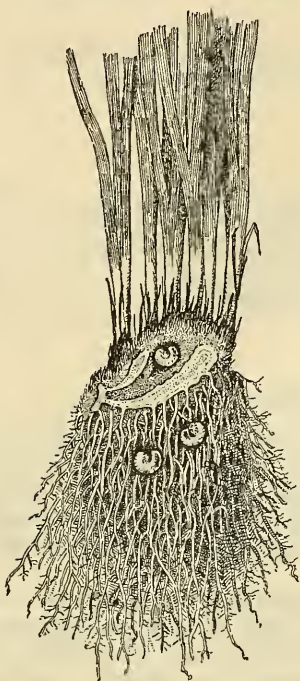


FIG. 1.—Japanese iris (*Iris kaempferi*):
The matted root system with Japanese beetle larvæ interspersed

tion of the great amount of experimental work required to test out each compound thoroughly the writers decided to limit the research to wormseed oil and carbon disulfide.

TABLE 1.—Results obtained from dipping third-instar larvæ of the Japanese beetle in various solutions

Compound	Concentration of solution	Larvæ ¹ dipped		Proportion of larvæ killed in soil ²	Effect of solution on plants ³
		Time in dip	Proportion killed		
		Hours	Per cent	Per cent	
Zinc chloride	5 per cent	2	0	0	Killed.
Wormseed oil	Saturated	6	100	100	Slight check.
Alpha naphthol	do	1	100	75	Killed.
Benzaldehyde	do	1	66	0	Do.
Beta-naphthol benzoate	do	1	0	0	Normal.
Carbon disulfide	½ saturated	1	100	100	Checked somewhat.
Carbon disulfide	Saturated	½	100	100	Checked badly.
Formaldehyde	5 per cent	1	100	0	Killed.
Furfural	3 per cent	1	0	0	Do.
Mercuric chloride	0.1 per cent	1	0	0	Injured badly.
Paraldehyde	8 per cent	1	0	0	Killed.
Pyridine	3 per cent	1	0	0	Do.
Petroleum ether	Saturated	1	0	0	Normal.
Thymol	do	1	100	90	Checked considerably.
Toluene	do	1	100	33	Checked.

¹ Larvæ not in soil.² Larvæ in pots of soil (light sandy loam) watered with a volume of the solution equal to the volume of the soil.³ Salvia, aster, nasturtium, and chrysanthemum.

OIL OF WORMSEED (AMERICAN)

American wormseed oil (*oelum chenopodii anthelmintici*) is distilled in Carroll County, Md., from the entire cultivated plant of *Chenopodium ambrosioides anthelminticum* Linné (family Chenopodiaceae).

In the ninth edition of the U. S. Pharmacopœia the oil of chenopodium, or oil of American wormseed, is described as a volatile oil distilled from the above-named plant. The oil is colorless or pale yellow, soluble in 8 volumes of 70 per cent alcohol, and varying in specific gravity from 0.955 to 0.980 at 25°C.

In recent years producers and dealers have urged that the U. S. P. standards for this oil should be lowered, basing their argument on the fact that authentic oils obtained at the stills do not come up to the standard. However, Russell (6)³ has shown conclusively that this shortcoming is due to faulty distillation, and that by distilling the herb with a large volume of steam during a relatively short period of time an oil can be produced that will meet all the U. S. P. requirements.

CHEMICAL COMPOSITION OF THE OIL

American wormseed oil (2) contains minute quantities of the lower fatty acids, chiefly butyric acid, and less than 0.5 per cent of methyl salicylate. Of the remainder of the oil at least 60 per cent is ascaridole, with about 5 per cent of the corresponding glycol and 30 to 40 per cent of a mixture of hydrocarbons made up approximately of cymene 15 per cent, α -terpinene 5 per cent, and a new laevorotatory terpene, 10 per cent.

Practically ⁴ pure ascaridole can be separated from oil of wormseed by a fairly easy process (4). The oil is fractionated under vacuum, the heat being kept low, for wormseed oil or, specifically,

³ The figures (italic) in parentheses refer to "Literature cited," p. 17.⁴ From correspondence with G. A. Russell.

ascaridole, suffers a molecular rearrangement when heated to 150° C. Consequently, if a vacuum of not over 6 millimeters is employed and the heat of the bath regulated the temperature of the oil need never be brought near 150° C. and the danger of explosion, owing to sudden molecular rearrangement of ascaridole, is virtually eliminated. Practically all of the first fraction up to 80° C. will consist of terpenes; the next fraction, which is ascaridole, boils at about 95° C. at 6 millimeters pressure, and the residue in the distilling flask contains some resinified products and considerable ascaridole glycol. To obtain pure ascaridole it is sometimes, in fact almost always, necessary to refractionate the ascaridole fraction.

The principal constituent of the oil, ascaridole, $C_{10}H_{16}O_2$, has a specific gravity of 1.0024 at 25° C., a disagreeable, benumbing odor, and a disagreeable taste. Ascaridole (so called because of its action against *Ascaridae*) is generally conceded to be the active ingredient of the oil, although some investigators state that the terpenes and the residue containing ascaridole glycol are also active. The writers have done some work on this point, with results reported later in this bulletin (Table 6).

Inasmuch as ascaridole is essentially the active ingredient of wormseed oil from the standpoint of toxicity toward insects, it is well to purchase the oil on the basis of ascaridole content rather than on that of price. A lot of oil containing 45 per cent of ascaridole at \$2.50 a pound is not as economical of the money invested as another lot of oil containing 65 per cent of ascaridole and priced at \$3, since the concentration of the dip for the control of the Japanese beetle larva is based on ascaridole and not on wormseed oil.

Under these circumstances it is advisable before buying oil in quantity to determine the ascaridole content by means of the method devised by Nelson (5). In a cassia flask, the neck of which holds 10 cubic centimeters, graduated in tenths, agitate thoroughly 10 cubic centimeters of the wormseed oil to be tested with 60 per cent acetic acid, made by mixing 60 parts by volume of glacial acetic acid with 40 parts of water. The flask is then filled to the mark with 60 per cent acetic acid and allowed to settle. The volume of undissolved oil is deducted from 10; the remainder, multiplied by 10, gives the volume percentage of ascaridole in the sample.⁵

Wormseed oil is but very slightly soluble in water, and for that reason an aqueous solution of it has very little promise as a dip for the control of the Japanese beetle larva. Under the circumstances, probably the only practical method of regulating the concentration of oil in the dip is to make an emulsion of the wormseed oil which, when added to the water, will disperse evenly.

WORMSEED-OIL EMULSIONS

Since this emulsion must be one that will disperse in water, it follows that water must be the external phase and wormseed oil the

⁵ G. A. Russell, in a letter to the writers, makes the following observations on this method of ascaridole assay: "This method is only approximate, but no other method is known. The 60 per cent acetic acid takes into solution any ascaridole glycol present in the oil, and thus the apparent percentage of ascaridole is increased. In well-prepared oils which are comparatively fresh the ascaridole glycol is present only in small amounts, so that including this in the determination of ascaridole means that only a small error is introduced, amounting to probably 4 or 5 per cent. I found that in order to get good results with this method the acetic acid solution must be made up fresh, using glacial acetic acid which has not stood in partly-filled containers for any length of time. That is the acetic acid should be fresh."

internal phase. Various hydrophile colloids such as soap, glue, gum arabic, etc., were tested in this connection as emulsifiers. In each case the colloid was dissolved in hot water, added to the wormseed oil, and shaken until the emulsion formed. In this manner 15 cubic centimeters of a 20 per cent gum arabic solution added to 10 cubic centimeters of oil gives a stable emulsion; 20 cubic centimeters of 0.5 per cent agar-agar and 5 cubic centimeters of oil produced a stable emulsion; 10 cubic centimeters of a 2 per cent glue solution added to 5 cubic centimeters of oil proved to be a very stable emulsion. Dextrin, saponin, and starch were found of little value in this connection.

While the results with miscellaneous colloidal emulsifiers as described above were satisfactory, the major part of the work was done with soap as the emulsifier, since this colloid appeared the most satisfactory of all. A commercial brand of caustic potash fish-oil soap diluted with water was mixed with the oil in varying proportions and shaken. In the majority of cases no emulsification occurred. Another procedure was then undertaken; the undiluted soap was first mixed very thoroughly with the oil, giving a so-called "miscible oil" which when mixed with water gave a perfect emulsion in the instances where sufficient soap was present. The length of time required for emulsification varied directly with the concentration of the soap.

STABILITY OF THE EMULSIONS

Emulsions were obtained with 20 cubic centimeters of oil and amounts of soap varying from 10 cubic centimeters down to 0.5 cubic centimeter. A mixture of 0.25 cubic centimeter of soap to 20 cubic centimeters of oil failed to produce an emulsion, probably owing to the fact that not sufficient soap was present to form a film at the oil-water interface.

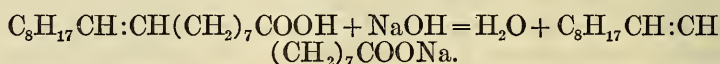
The question therefore arose as to the optimum amount of soap. It was thought that within certain limits the greater the amount of soap present the more thorough would be the division and the smaller the size of the oil globules; in other words, the finer the water suspensions and the more stable the emulsion the greater would be the number of oil globules, the greater the surface of the oil-water interface, and, therefore, the greater the amount of soap necessary. If this hypothesis is accepted it must be assumed that there would be either an increase in the size of the oil globule with the decreased amount of soap or a diminution in the thickness of the soap film on the surface of the globule. Upon measurement it was found that there was an actual increase in the size of the globule, thus explaining the decreased stability of the emulsion with the decreased amount of soap. The measurements are given in Table 2.

TABLE 2.—*Stability of wormseed-oil emulsions prepared with potash fish-oil soap*

Emulsion number	Ingredients of emulsion			Size of globules	Remarks
	Soap	Oil	Water		
	<i>C. c.</i>	<i>C. c.</i>	<i>C. c.</i>	<i>Microns</i>	
1.....	10	20	10	1 to 12.....	Stable; best emulsion.
2.....	5	20	10	2 to 16.....	Stable.
3.....	2.5	20	10	4 to 32.....	Unstable.
4.....	1	20	10	6 to 42.....	Unstable.
5.....	0.5	20	10		Unstable.
6.....	0.25	20	10		Did not emulsify.

From these measurements it is apparent that there is an optimum proportion of soap above which there is on standing a marked separation of the soap from the emulsion and below which there is a tendency for the globules to increase in size to such an extent that the mixture either fails to emulsify or easily breaks after emulsification.

Soaps vary greatly in emulsifying power, some brands being useless and, in fact, two batches of the same brand may vary greatly in emulsifying power (7). Under these circumstances the writers found it necessary to test each purchase of soap before emulsifying any quantity of wormseed oil for experimental purposes. In practice, in the hands of the novice, any deficiency in the soap used might easily result in an unstable emulsion. The writers therefore made a series of tests to determine the possibility of preparing wormseed-oil emulsion by means of such standard materials as oleic acid and sodium or potassium hydroxide, according to the equation—



In making these emulsions the oleic acid was added to the oil and shaken, then N/10 NaOH or N/10 KOH was added. The mixture emulsified immediately.⁶ The various tests are compared in Table 3.⁷

In using these emulsions in practice it seems advisable either to use the oleic acid or, if a commercial brand of soap is employed, to be absolutely sure by test that the material will produce a stable emulsion.

TABLE 3.—*Preparation of wormseed-oil emulsions with oleic acid and an hydroxide*

Emulsion number	Quantities of—		N/10 NaOH	Remarks on emulsions formed
	Oil	Acid		
1 A.....	C. c. 20	C. c. 0.12	C. c. 3.76	Oil separated out in 1 hour.
2 A.....	20	0.24	7.56	Oil separated out in 1 hour.
3 A.....	20	0.40	12.60	Stable emulsion. Best of series.
4 A.....	20	0.80	25.20	Stable emulsion.
5 A.....	20	1.20	37.80	Stable emulsion.
6 A.....	20	1.60	50.40	Curdy emulsion. Too much emulsifier.
7 A.....	20	2.00	63.00	Curdy emulsion. Too much emulsifier.

Emulsion	Quantities of—		N/10 KOH	Remarks on emulsions formed
	Oil	Acid		
8 A.....	20	0.20	6.30	Oil separated out.
9 A.....	20	0.40	12.60	Stable emulsion. Best of series.
10 A.....	20	0.60	18.90	Stable emulsion.
11 A.....	20	0.80	25.20	Stable emulsion.
12 A.....	20	1.00	31.50	Stable emulsion.

⁶ The molecular weight of oleic acid is 282.37 and its specific gravity is 0.89; it follows that 317.3 cubic centimeters of the acid will make a normal solution. Therefore 317.3 cubic centimeters of oleic acid is neutralizable by 1,000 cubic centimeters of normal sodium hydroxide, or 0.03173 cubic centimeter of oleic acid by 1 cubic centimeter N/10 sodium hydroxide. Conversely, 1 cubic centimeter of oleic acid is neutralizable by 31.5 cubic centimeters of N/10 NaOH.

⁷ The writers have been guided in the preparation of these emulsions by Clayton (1).

TOXICITY OF WORMSEED-OIL EMULSIONS

The dip made with emulsion of oil of wormseed was tested in three different ways: (1) Larvæ, free from soil, were submerged in the dip for varying periods to determine the time necessary to kill them at various temperatures. (2) A similar series of exposures was made with larvæ embedded in soil. (3) Plants infested with the larvæ were immersed in the dip under varied conditions of temperature and length of exposure to determine the toxicity of the material to the larvæ under natural conditions and the resistance of the plants to the insecticide. The entire crop of one of the local nurseries was treated in this test, which was carried out under commercial conditions.

TOXICITY OF WORMSEED OIL TO JAPANESE BEETLE LARVÆ

The toxicity of the emulsions of wormseed oil to the larvæ of the Japanese beetle was determined by submerging the larvæ, free from soil, in the dip for varying periods of time at various temperatures. Emulsion 1 as listed in Table 2, and emulsions 3A and 9A of Table 3, were employed in these tests in the proportions of 1 cubic centimeter of ascaridole to 6 liters of water. The wormseed oil employed assayed 75 per cent ascaridole by the acetic acid method already described. The results of these tests are presented in Table 4. It will be observed that the best results were obtained when the temperature of the dip was maintained at 65° or 70° F. Lower temperatures reduced the toxicity of the material.

TABLE 4.—*Toxicity of wormseed-oil emulsions to Japanese beetle larvæ (not in soil)*¹

Temperature of dip		Percentage of larvæ killed by immersion in dip for hours specified.											
		3	4	5	6	7	8	9	12	15	18	21	24
° F.	° C.												
50	10	-----	-----	-----	50	-----	-----	75	75	75	100	100	100
60	16	0	-----	-----	75	-----	-----	100	100	100	100	100	100
65	18	25	50	25	100	100	100	100	100	100	-----	-----	-----
70	21	0	50	75	100	100	100	100	100	-----	-----	-----	-----

¹ A total of 500 larvæ were used in the tests on which this table is based. In each instance here recorded the larvæ were immersed for the specific time, and the percentage of those killed is tabulated. In each case the dip contained ascaridole in the proportion of 1 cubic centimeter to 6 liters of water.

TOXIC STABILITY OF WORMSEED-OIL EMULSION

In the course of the experimental work several samples of the emulsion of various ages accumulated. These were tested under identical conditions and all on the same day in order to determine whether the stock emulsion on standing had undergone any change which might affect its toxicity. The results of these tests are given in Table 5. It will be observed that the emulsion did not decrease in toxicity within the space of 40 days. The results indicate that the toxicity will persist indefinitely if the emulsion is kept in a cool place, since the chemical change, if any, is slow.

TABLE 5.—*Comparative toxicity of stock wormseed-oil emulsions of various ages*¹

Age of stock emulsions in days	Percentage of larvæ killed by immersion in dip for hours specified						
	5	6	7	8	9	10	15
1.....	50	100	100	100	100	100	100
3.....	75	100	100	100	100	100	100
14.....	100	100	100	100	100	100	100
23.....	100	100	100	100	100	100	100
30.....	75	100	100	100	100	100	100
40.....	75	100	100	100	100	100	100

¹ All the emulsions subjected to this test contained 1 cubic centimeter of ascaridole to 6 liters of water. The test was applied at a uniform temperature of 70° F. (21° C.). A total of about 800 larvæ were used in the tests on which this table is based.

COMPARATIVE TOXICITY OF THE INDIVIDUAL INGREDIENTS OF WORMSEED OIL

As already stated, wormseed oil when distilled under a vacuum of approximately 6 millimeters pressure can be separated by proper technique and control of temperature into three fractions consisting mainly of (1) terpenes, (2) ascaridole, and (3) a residue containing principally ascaridole glycol. However, in separating the oil into fractions for determining the toxicity of its several constituents, four fractions were made, of which the first consisted mainly of terpenes, the second of a mixture of terpenes and ascaridole, of which the terpenes constitute the major portion, the third of practically pure ascaridole, and the fourth a residue consisting principally of ascaridole glycol. Data on the relative toxicity of these ingredients are presented in Table 6.⁸

In making up the individual dips for the tests, material from each fraction was emulsified with soap, using 10 cubic centimeters of soap, 10 cubic centimeters of water, and 20 cubic centimeters of the material, as was done with the wormseed oil in making the first and most satisfactory emulsion in testing the stability of emulsions, as recorded in Table 2. For each test to 6 liters of water was added 3.67 cubic centimeters of the emulsion. It will be noticed that all the ingredients of the oil are toxic to the larvæ. The ascaridole was completely fatal to larvæ in 5 hours, the terpenes in 8 hours, and the residue in 12 hours. The results merely emphasize the fact already stated that in buying oil of wormseed it is advisable to purchase primarily on the basis of ascaridole content rather than on that of price.

⁸ With respect to the ascaridole glycol of the fourth fraction, the following excerpt from a letter from G. A. Russell, by whom it was fractionated and assayed, may be of interest: "I have never done any work on the keeping qualities of wormseed oil, but Nelson examined five samples of American oil which had been shipped to Brazil and subsequently returned to the United States, all of which were at least 1 year old. He found that the distillate residues, while higher than those found in fresh oil, were not excessive, and concluded from this that the oil does not deteriorate very rapidly with age. It is my opinion that oil preserved in well-filled containers will keep without appreciable change for a period of at least 1 year. This glycol is formed by the rearrangement of the ascaridole molecules, and apparently is produced by the action of the steam on the ascaridole at the time of distillation. This may account for the high percentages of residue obtained when fractionating oils distilled by means of low-pressure steam over a relatively long period of time."

TABLE 6.—Comparative toxicity of four fractions of wormseed oil ¹

Fraction	Properties at 25° C.					Percentage of larvæ killed by immersion in dip for hours specified					
	Specific gravity	(Δ) (D)	(N) (D)	Solution in 70 per cent alcohol	Solution in 60 per cent acetic acid	5	6	7	8	12	24
First.....	0.858	—Strong.	1.4805	None.....	<i>Per cent</i> 8	50	75	25	100	100	100
Second.....	0.950	—8.73°	1.4760	6.5 vols....	62.5	100	100	75	100	100	100
Third (ascaridole fraction).....	1.0024	—2.41°	1.4720	1.4 vols....	100	100	100	100	100	100	100
Fourth (residue).....	1.0181	—2.53°	1.4780	0.5 vol....	97	75	100	75	75	100	100

¹ Temperature of dip in each case, 70° F. (21° C.). The larvæ were immersed for the specified number of hours in the dip prepared from the fraction tested, and the percentage of those killed is tabulated. A total of about 300 larvæ were used in these tests.

APPLICATION TO LARVÆ IN SOIL AND PLANTS

The results given in Table 4 indicate the action of wormseed-oil emulsion dip upon the larvæ when the latter are removed from their habitat (the soil) and dipped. The larvæ are killed in six hours at a temperature of 70° F. When, however, the soil containing larvæ or infested plants (such as iris or phlox) is dipped in the material, it must be submerged for a longer period in order to kill all the larvæ present. The soil itself apparently absorbs the toxic material from the dip and interferes to some extent with the insecticidal action of the material upon the larvæ. This phenomenon of soil absorption and its relations to the use of soil insecticides has been discussed at considerable length in a previous paper by Leach and Thomson (3, p. 58), and summarized as follows:

Dipping tests indicate that certain compounds in solution, capable of producing a gas insoluble or only slightly soluble in water, are toxic to *Popillia* larvae. These compounds may be divided into two classes: (1). Compounds slightly soluble in water, e. g., carbon disulphide, thymol, mustard oil, etc. (2). compounds readily soluble in water, such as sodium sulphocarbonate and sodium ethyl xanthate. These compounds in solution, on being decomposed by organic acids, yield carbon disulphide, the active killing agent.

Saturated solutions of compounds in class 1 (about 1 to 1,000) readily kill *Popillia* larvae when the latter are removed from the soil and dipped in the solution for a definite period of time. However, when *Popillia* larvae are embedded in a soil-ball and the latter dipped in these solutions the grubs contained within the soil-ball remain unharmed. Soil adsorption, or, in other words, physical "locking up" of the compound in solution by the moisture film surrounding the minute soil particles, is the apparent reason for the failure of these relatively dilute solutions to function in soil. That portion of the compound adsorbed by the soil is apparently rendered impotent as far as its ability to produce larval mortality in the soil is concerned.

Compounds of class 2, when used in dilute solutions give results comparable to those obtained by the use of compounds in class 1. However, when compounds of class 2 are employed in relatively concentrated solutions, a quantity of the compound sufficient to produce 100 per cent mortality of *Popillia* larvae remains free in the soil after the soil particles have adsorbed the compound to the limit of their capacity.

However, in the treatment of such plants as Japanese iris, phlox, and sedum, the limitation above noted does not preclude success in killing the larvæ present in the root mass, for, while *some* soil is

present, it is confined to small amounts which can not be shaken out or otherwise removed before treatment. The presence of this small quantity of soil simply slows down the action of the wormseed-oil emulsion dip and necessitates a longer period of dipping to secure mortality of the larvæ under these conditions than is the case when the latter are entirely free from soil.

TABLE 7.—Results obtained in dipping *Popillia* larvæ (in soil balls) in wormseed-oil emulsion dip¹

Dosage (ascaridole per 6 liters of water)	Percentage of larvæ killed by immersion in dip for hours specified				
	6	12	15	18	24
1.0 cubic centimeter-----	50	100	100	100	100
2.0 cubic centimeters-----	75	100	100	100	100

¹ The larvæ were immersed for the specified time at a temperature of 70° F. (21° C.), and the percentage of those killed is tabulated. A total of about 250 larvæ were used in the tests on which this table is based.

The results of dipping soil containing larvæ are presented in Table 7. The method adopted in this phase of the work was as follows:⁹ Fifty iris plants were thoroughly shaken and the soil thus removed discarded. The plants were then cut to pieces and every vestige of soil removed and saved. This was measured by volume and averaged 7 cubic centimeters per plant. Ten cubic centimeters of soil containing a *Popillia* larva was wrapped in a small bag of muslin and the bag tied at the throat with twine. A sufficient number of such bags, each containing one larva, were used for the dipping tests the results of which are presented in Table 7. It will be noted that the 1 cubic centimeter ascaridole dosage was completely effective in 12 hours, while twice this concentration did not decrease the period of dipping necessary to secure a complete mortality. On the other hand, only six hours of dipping are required for killing the larvæ when no soil is present. This difference of six hours in the period of submergence necessary to kill the larvæ when soil is present is due to the partial soil absorption and consequent slowing up of the action of the toxic material. Were large quantities of soil present not all the larvæ could be killed even with long-sustained dipping. In practice, therefore, the large clumps of iris are broken up into several smaller ones and the greater bulk of the soil removed by thorough shaking.

During much of the fall and spring shipping seasons for iris, phlox, etc., the ground is cold. The question arose as to whether larvæ in this cold soil, when dipped, would be resistant to the insecticide. As a result of a series of experiments on this point, it was found that no difference in anything but the rapidity of killing resulted, whether the soil and larvæ were warm or cold before or after being dipped, provided the temperature of the dip itself was not lowered while the larvæ were submerged. However, the immersion of large quantities of cold soil or plants in the dip appreciably lowers its temperature and thereby reduces its toxicity. For this reason it is advisable to

⁹ The infestation of iris, phlox, sedum, etc., by *Popillia japonica* in the infested area at the present time is light, not more than 5 to 10 per cent of the plants being infested. Further, these plants are expensive. These two facts render it almost impossible to obtain the preliminary data by natural means, since the procedure would involve the use and destruction (by cutting) of thousands of plants. The method here described was therefore adopted and the results checked and confirmed by the dipping of several thousand plants and their examination to determine the effect of the toxic material upon the larvæ present.

warm the plants in a room at 70° F. for 48 hours before dipping, and to keep the plants at 70° F. for 48 hours after removal from the dip, in order to promote the larval mortality.

TREATMENT OF JAPANESE IRIS

The roots of Japanese iris (*Iris kaempferi*) are mainly dug in the fall, beginning in September, and shipped immediately for planting. In September tests were made of the susceptibility of these plants to the wormseed-oil emulsion. Twelve plants were immersed for periods of 6, 12, 15, 18, and 24 hours, respectively, in a dip containing 1 cubic centimeter of ascaridole per 6 liters of water, at a temperature of 70° F. (21° C.), and the treated plants healed in or planted in the nursery for further observation. Similar tests were made at the same temperature and for the same periods of immersion, but in a dip of twice the strength, i. e., 2 cubic centimeters of ascaridole to 6 liters of water, with the same subsequent treatment. Without exception, the plants came through the tests unhurt, and began to throw out new roots and leaf growth within a few days. The plants apparently withstand nearly twice the period of immersion in twice the concentration of dip necessary to insure mortality of the larvæ present in the roots.

TREATMENT OF PERENNIAL PHLOX

In this section plants of perennial phlox are dug in the fall, some when in full bloom to fill early orders, and the remainder from that time on until the ground freezes. Care is taken in digging to secure as much of the root system as possible, since the long roots are severed about 3 inches from the stock, cut into 1½-inch pieces, and the pieces sown in coldframes. These root cuttings begin to grow early in the following spring, and are later set out in the field to produce the year's crop. The mature plants, having been trimmed in the manner described, are packed in damp moss and placed in cold storage at 32° F. until February or early March, when they are removed, potted, and placed in the greenhouse and forced slightly for the spring trade.

It is evident that an insecticide employed to kill any larvæ present in or among the roots of this plant must be absolutely nontoxic to the roots, stock, and buds. Tests with wormseed-oil emulsion dip for the control of the larvæ in phlox roots were accordingly made at all stages of the harvesting and storage season. The results, the plants in every case being unhurt, indicate that wormseed-oil emulsion is a safe material to use as a means of killing any larvæ present in phlox during the period of harvesting and storing it.

Plants were dug when in full bloom, and separate lots, each of 12 plants, immediately dipped, all at a temperature of 70° F., but each lot for a specified time and in a dip of specified strength. Four lots were dipped for periods of 6, 7, 8, and 9 hours, respectively, in a dip containing 1 cubic centimeter of ascaridole to 6 liters of water, and three lots for periods of 6, 7, and 8 hours, respectively, in a dip containing twice the proportion of ascaridole. All of these plants came through the treatment unhurt. Immediately after dipping they were set out in the nursery out of doors, and made a normal growth during the subsequent spring and summer, the blooms on the treated plants having in many cases a diameter of 6 to 8 inches.

Three similar lots, each of 12 plants, were dug after the first heavy frost and immersed for periods of 6, 9, and 12 hours, respectively, in a dip containing 1 cubic centimeter of ascaridole to 6 liters of water. The roots had not previously been trimmed, but, after dipping, the roots were cut off and divided into 1½-inch pieces and planted in a coldframe. They developed normally in the spring, but were somewhat slow in beginning growth. The roots of the plants of three other similar lots, each of 12 plants, were trimmed and cut into pieces, after which both plants and root cuttings were immersed in a dip like that for the other three lots and for the same periods, respectively. These root cuttings were planted in the same manner as those of the other three lots and made the same growth in the spring. The mature plants of all six lots were placed in cold storage until February 1, when they were potted and placed in the greenhouse, where their growth was equal to that of the controls and in many cases superior.

Still other plants were removed from cold storage February 1 and three lots, each of 12 plants, immersed for 6, 9, and 15 hours, respectively, in a dip containing, as before, 1 cubic centimeter of ascaridole to 6 liters of water. Twenty-four hours after removal from the dip these plants were potted and placed in the greenhouse. Their growth there was superior to that of the controls.

TREATMENT OF SEDUM SPECTABILE

The showy sedum, *Sedum spectabile*, has a coarse, matted root system and is frequently infested with the larvæ of the Japanese beetle. To test the efficacy of wormseed oil as a protective dip, four lots, each of six plants of this species, were dug in the early spring, the surplus soil adhering to the roots removed by shaking, and the four lots immersed for 12, 15, 18, and 24 hours, respectively, in a dip of wormseed-oil emulsion containing 1 cubic centimeter of ascaridole to 6 liters of water and at a temperature of 70° F. All came through the treatment without injury to the roots. At the time of dipping, the plants had made about 3 inches of top growth. This was injured by the dip and sloughed off, but on potting the plants and placing them in the greenhouse, the treated plants soon threw out new top growth and prospered, soon catching up with the controls.

VALUE OF WORMSEED OIL AS AN INSECTICIDE

The results of the experimental work which has been described in the preceding pages indicate that a dip the insecticidal basis of which is wormseed-oil emulsion is, under certain conditions, a reliable destroyer of the larvæ of the Japanese beetle, though not rapid in its action. Of all the compounds tested for this purpose it is the least toxic to plants. The cost of treatment with this insecticide is not prohibitive; 1 pound of wormseed oil, assaying 75 per cent ascaridole, will make 500 gallons of dip. It seems probable that this treatment could be utilized in many similar cases of needed control of insects.

TREATMENT OF PEONY ROOTS

Figure 2 represents a typical peony root, the root cavity being split open to show its characteristics as a hiding place for the larvæ of the Japanese beetle. In the majority of peony roots the cavities contain more or less soil, usually compact and in one solid mass; whereas in iris the soil is interspersed in very small individual amounts through

the tangled root mass, but is appreciable in the aggregate. Experimental work has shown that it is much easier to kill the larvæ in iris roots than in peony roots because of the difference in the distribution of the soil. Here, again, soil-absorption is apparently the limiting factor. A larva in the center of a cubic inch of soil is not affected to nearly the same extent by the dip as a larva in the center of a mass of soil and roots consisting of 1 cubic inch of soil mixed with 3 cubic inches of roots, when both are submerged in the same concentration of dip. In fact, the submergence of iris roots for 15 hours in a dip containing 0.5 cubic centimeter of ascaridole per 3 liters of water at 70° F. completely killed the larvæ in them; whereas twice this dosage was required for killing the larvæ in peony roots under the same conditions of time and temperature. Incidentally the peonies were not injured by a dip of this greater strength when submerged for the time stated, but the added cost of the dip, while not prohibitive, led the writers to experiment with other toxic materials in emulsion as a control for the larvæ infesting this particular plant. Of the materials tested in this connection carbon disulphide was found to be the most feasible.

CARBON-DISULFIDE EMULSIONS

EMULSION 1

Experimental work showed that carbon disulfide could be emulsified by soaps in general, and the writers found the old style rosin-fishoil soap to be the best for this purpose. It is a thick, heavy soap and must be heated with water to dissolve it. When it is available a stock soap solution can be made by adding 12.5 grams of rosin-fishoil soap to 87.5 cubic centimeters of water, heating until dissolved and allowing the solution to cool. Add 20 cubic centimeters of this stock solution to 50 cubic centimeters of carbon disulfide in an Erlenmeyer flask and agitate until the ingredients emulsify, which will require but a few minutes. Larger quantities, using the same proportions, may be emulsified with a butter churn or ice-cream freezer. The emulsion proper is white and has the consistency of thick cream. When added to water it disperses evenly and remains indefinitely in suspension.

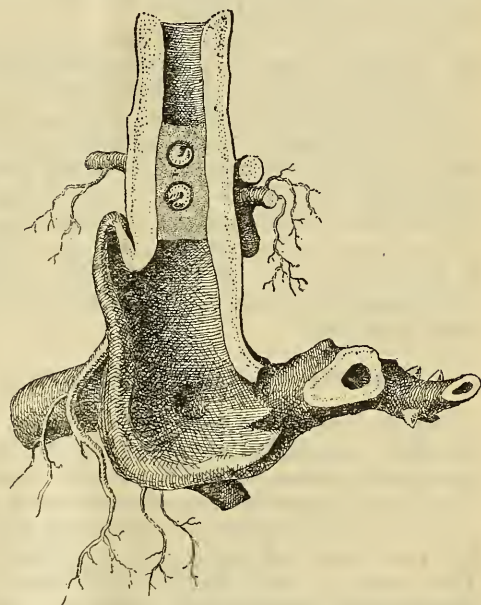


FIG. 2.—Peony root, divided longitudinally, showing infestation by larvæ of the Japanese beetle

EMULSION 2

Where the old style rosin-fishoil soap is not available a good emulsion may be made by mixing 0.5 cubic centimeter of oleic acid

with 20 cubic centimeters of carbon disulfide and adding N/10 KOH or N/10 NaOH until the solution is about neutral to phenolphthalein, 10 cubic centimeters of the hydroxide being ordinarily required.

Theoretically, about 18.3 cubic centimeters of N/10 potassium or sodium hydroxide is required to neutralize 0.5 cubic centimeter of oleic acid, but in tests by mixing the acid with carbon disulfide it was found that only 10 cubic centimeters of N/10 hydroxide was required. This may be due to the solvent action of the carbon disulfide upon the oleic acid, thus limiting the necessary neutralizing action of the potassium hydroxide on the oleic acid at the surface of the carbon disulphide globules, the acid in solution in the interior of each individual globule probably not being acted upon. The necessity for less than the theoretically correct amount would naturally result from this condition.

In the case of both of these carbon-disulfide emulsions water is the external phase and carbon disulfide the internal phase, with a hydrophile colloid as the emulsifier.

Carbon-disulfide emulsion was tested along three lines: (1) Larvæ (not in soil) were submerged in the dip for various periods, to determine the time necessary at various temperatures for the dip to be completely effective. (2) Peony roots infested with larvæ were dipped for various periods to determine the toxicity of the material to the larvæ under natural conditions and the resistance of the plant to the insecticide. (3) The method was tested out under commercial conditions involving the treatment of the entire crop of one of the local nurseries.

TOXICITY OF CARBON-DISULFIDE EMULSION TO LARVÆ

Larvæ free from soil were dipped in dilutions of the carbon-disulfide emulsion at different temperatures and for different periods of treatment and the results noted. Two dips were used, one of 4.2 cubic centimeters of emulsion 1, and the other of 4.57 cubic centimeters of emulsion 2, each to 6 liters of water. The results for the two were not separately recorded, the preference being slight. The results in larvæ killed for different temperatures and periods of exposure are presented in Table 8. It is evident that the optimum temperature lies between 60° and 70° F., the latter being preferable, and that much of the effectiveness of the dip depends upon a temperature not too low.

TABLE 8.—*Toxicity of carbon-disulfide emulsion to larvæ of the Japanese beetle (not in soil)*¹

Temperature of dip (° F.)	Percentage of larvæ killed by immersion in dip for hours specified											
	3	4	5	6	7	8	9	12	15	18	21	24
50.....				25	25	50	75	100	100	100	100	100
60.....	75	100	100	100	100	100	-----	-----	-----	-----	-----	-----
65.....	100	75	100	100	100	100	-----	-----	-----	-----	-----	-----
70.....	50	100	100	100	100	100	-----	-----	-----	-----	-----	-----

¹ The larvæ were immersed for the specified time, and the percentages of those killed are tabulated. A total of about 400 larvæ were used in these tests.

APPLICATION OF CARBON-DISULFIDE EMULSION TO LARVÆ AND PEONIES

Larvæ were placed in the cavities of the peony roots and the cavities then filled and plugged with soil. The plants thus artificially infested were dipped in various dilutions of the carbon-disulfide emulsion for various periods of time but always at a temperature of 70° F. Forty-eight hours after removal from the dip the larvæ were taken from the root cavities and the mortality determined; the plants themselves were set out in the nursery row and kept under observation for possible injury to the buds and rootstocks. This test is of interest in connection with the treatment of plants for the fall and spring shipping seasons.

Three series of treatments were tried, each series with a particular strength of solution and varying periods of time. For the first, a dip of 4.2 cubic centimeters of emulsion 1, and one of 4.5 cubic centimeters of emulsion 2, to 6 liters of water, the two considered as of equal strength, were used, and peony roots infested as just described immersed in one or the other solution for 6, 9, 12, 15, 18, and 24 hours, respectively. Plants containing in all four larvæ were submerged for each of the periods named. The peonies were uninjured by the treatment except that the bud scales were blackened by the 24-hour exposure. All the larvæ exposed for 12 to 24 hours, inclusive, were killed; for each of the other two treatments but one larva was killed, the other three coming out alive.

Dips were tried of twice the strength, 8.4 cubic centimeters of emulsion 1 and 9.14 cubic centimeters of emulsion 2, each to 6 liters of water, with immersions of 6, 12, 18, and 24 hours, respectively, four larvæ with the plants containing them being used in each case. All the larvæ were killed. The peonies were badly checked by the shortest exposure and killed by all the others.

The strength of dip was again doubled, 16.8 cubic centimeters of emulsion 1 and 18.28 cubic centimeters of emulsion 2, each to 6 liters of water being used. Four larvæ, with the plants containing them, were immersed as before for the several periods of 6, 12, 18, and 24 hours. In all cases plants and larvæ were killed.

COMMERCIAL USE OF EMULSIONS

In treating peony, iris, phlox, and sedum plants infested with *Popillia* larvæ the writers have found it best to pack the plants in tubs until nearly level with the top. Galvanized-iron tubs are best for this purpose since they rarely leak, as is the case with wooden tubs, and they do not absorb the toxic material from the dip.

In cold weather the plants should be allowed to warm up for 24 hours in a room kept at a temperature of 70° F. before being dipped, and the actual dipping should be performed in a room maintained at this temperature.

The water for the dip should be brought to a temperature of 75° F. In our experience, extra tubs are best for this purpose. When the water is heated to 75° F., stir in the required amount of emulsion and pour the mixture into the tubs containing the plants, being sure that *all* the plants are submerged.

The dosage and period of submergence for the various plants are as follows:

Japanese iris.—Dosage, 1 cubic centimeter ascaridole to 6 liters of water. Allow plants to remain submerged for 15 hours.

Perennial phlox.—Same dosage as for iris. Keep in the dip for from 9 to 18 hours, depending on the amount of soil present on the plants.

Sedum.—Same dosage as for iris. Dip for a period of from 15 to 18 hours.

Peony.—Dosage, 0.5 cubic centimeter carbon disulfide per liter of water. Dip for a period of 15 hours.

Care should be taken that the temperature of the dip does not fall below 65° F. at any time during the treatment. At the end of the period of submergence the plants should be removed from the dip, the latter discarded, and the plants, after draining, kept for 48 hours in a room at 70° F. Care must be taken that the plants do not dry out before or after the dipping. Plants so treated are then ready for shipment outside the quarantined area¹⁰ and not before. Any chilling subsequent to the treatment should be carefully avoided, as it may lengthen the time required to kill all the larvæ.

COMMERCIAL EXPERIENCE WITH THE METHODS

During 1922 and 1923 the writers treated by the above methods approximately 10,000 Japanese iris, 10,000 perennial phlox, 1,000 sedum, and 15,000 peony, valued in all at \$10,000. There have been to date no complaints from the quarantine officials or consignees.

SUMMARY AND CONCLUSIONS

Plants of the nature of Japanese iris, phlox, sedum, etc., have a matted root system, while peonies are hollow-rooted. It is impossible to eliminate larvæ of the Japanese beetle which may be present in these roots by such means as removal of the dirt, by washing or by other ordinary methods. The experimental work here outlined was therefore conducted for the purpose of evolving a chemical dip in which such plants could be immersed for definite periods of time, to make sure of killing any larvæ present, and with no resulting injury to the plant.

The results of the work indicate that oil of wormseed (American) and carbon disulfide are the best materials to use for this purpose. These substances, when added to a hydrophile colloid and water, are both capable of forming stable emulsions the toxic principle of which is retained indefinitely.

Oil of wormseed (American).—The primarily active ingredient of oil of wormseed is ascaridole, ($C_{10}H_{16}O_2$). Other ingredients of the oil are also toxic in varying degrees. For greater certainty the concentration of the dip is figured in terms of ascaridole rather than in terms of wormseed oil.

When Japanese beetle larvæ, with no soil present, are immersed for six hours in a wormseed-oil dip the concentration of which is equal to 0.5 cubic centimeter of ascaridole to 3 liters of water, the larvæ are killed, provided the temperature of the dip is maintained between 65° and 70° F. The experimental results clearly indicate that the temperature of the dip is the limiting factor in the success of this method, and under no circumstances must it be allowed to fall below 65° F. during the course of the treatment. It is advisable to maintain it at 70° F.

¹⁰ No injury has occurred as a result of the wetting received by the plants. In two series of experiments, plants were taken out of the dip and immediately packed in damp moss. One lot was placed in cold storage for two months and the other next to a hot stove for several weeks. The first lot was normal when removed from storage, whereas the second lot made 6 inches growth in the moss.

When plants infested with larvæ are immersed in the wormseed-oil dip, it has been found that longer periods of submergence are required to insure complete larval mortality. This is due to the fact that the soil present in the roots absorbs to a certain extent the toxic material, thereby slowing up its action upon the larvæ. As a result of the research here described it is recommended that Japanese iris and sedum be immersed for 15 hours, and perennial phlox for from 9 to 18 hours, the time depending on the amount of soil present in the roots. These periods of dipping provide ample margins of safety over the time actually required to obtain mortality of the larvæ under these conditions, while the plants concerned are unaffected by the treatment.

Carbon disulfide.—In the case of peony roots it has been found advisable from the standpoint of cost to use a carbon disulfide emulsion dip. The plants should be immersed for a period of 15 hours in a dip the concentration of which is equal to 0.5 cubic centimeter of carbon disulfide (emulsified) to 1 liter of water. The same limitations of temperature apply in the use of this material as in the case of the oil of wormseed.

Commercial experience with these emulsions in 1922 and 1923, involving the treatment of 45,000 plants of this nature, valued at \$10,000, indicate that when applied under Government supervision the method is satisfactory to the quarantine officials and to the nurserymen from the standpoint of cost and the safety of the plants.

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May 14, 1925

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BIOLOGICAL STUDIES OF THE GREEN CLOVER WORM

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INTRODUCTION ¹

The green clover worm, *Plathypena scabra* Fabr., has long been recognized as a pest of wide distribution and injurious to various crops. In 1914 and 1915 it occurred in abundance in alfalfa fields in the vicinity of Nashville, Tenn., and studies on its life history were commenced by the writer at that time. During the summer of 1919 a general outbreak of this pest on different crops occurred of sufficient severity to attract the attention of agriculturists throughout a large portion of the East. A popular account with recommendations for control as an alfalfa pest, based on studies conducted by the writer in Tennessee, was published (5) ² in 1918. The present bulletin embodies technical details regarding the biology of this insect which necessarily were omitted in the popular account.

SYSTEMATIC HISTORY

Owing to sexual dimorphism in this species, the sexes were originally considered as distinct species, a mistake which was not discovered until 1873, when Lintner (?), through study of his own collection and those of others, found that the species, then known as *Hypena scabra* Fabr. and *Hypena erectalis* Guen., were each represented in collections by a single sex. He communicated this observation to Grote, who substantiated it by further examinations; and later in the year both men published the fact that *erectalis* Guenée was merely the female form of *scabra* Fabricius, of which heretofore only the male form had been known. Grote (3), in his paper, erected for the species the genus *Plathypena*.

¹ The author expresses his appreciation of helpful suggestions, received from Geo. G. Ahlström, under whose direction work on this insect was first started at Nashville, Tenn., and to Carl Heinrich for guidance in the construction of pupal and setal charts.

² Reference is made by number (italics) to "Literature cited," p. 19.

SYNONYMY

The following synonymy is given in Barnes and McDunnough's list (1):

Plathypena Grt.
 scabra Fabr.
 erectalis Gn.
 palpalis Hav.
 obesalis Steph.
 ab. *subrufalis* Grt.

GEOGRAPHICAL DISTRIBUTION

A study of all the available definite locality records shows that the species occurs throughout the United States and southern Canada east of the ninety-eighth meridian, except possibly along a portion of the Gulf coast and southern Florida, from which sections no data have been secured by the writer. The infested territory is represented by the shaded area in the map (fig. 1).

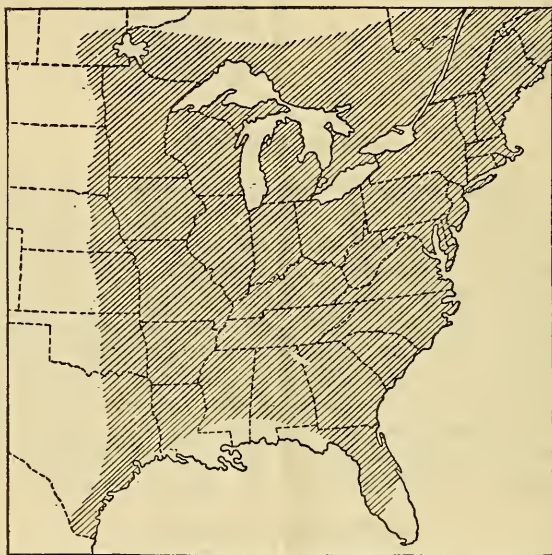


FIG. 1.—Map showing distribution of the green clover worm in the United States

FOOD PLANTS

The larvæ ordinarily feed on leguminous crops, and among forage crops are most frequently found on alfalfa, red clover, soybean, and cowpea. In Tennessee alfalfa seemed to be preferred above all other food plants. This was further demonstrated by caged material. Larvæ left in a cage containing red clover, cowpeas, blackberry, strawberry, and alfalfa attacked and stripped first the alfalfa plants.

In addition to these crops, Chittenden (2) recorded the larvæ from vetch and Lima bean, also at different times from both strawberry and blackberry, and in great numbers on tickweed, all in the vicinity of Washington, D. C.; E. H. Gibson found one feeding on sweet-clover and swept two more from the same plant; P. Luginbill reported

it injuring velvetbean, and Riley (9) stated that it fed on Robinia. In food-plant experiments conducted in Tennessee, larvæ were reared from egg to adult on common vetch, willow, strawberry, blackberry, and wild carrot, and they were found to feed greedily on dwarf Lima bean, white clover, alsike clover, tickweed, and common cinquefoil, and would undoubtedly mature on these plants under favorable conditions. Smartweed (*Persicaria pennsylvanica*) and morning-glory (*Ipomoea purpurea*) were eaten to some extent, and G. G. Ainslie found a partly grown larva on *Lespedeza procumbens*, upon which he succeeded in rearing it to adult.

In several instances larvæ have been found on grasses. P. Luginbill found a specimen on millet, and others on the leaves of *Paspalum dilatatum*. E. S. Cogan swept larvæ from grasses at the edge of a clover field, and E. H. Gibson swept them from grass and weeds growing in wheat stubble and along roadsides. None were seen in the act of feeding, and in each case it was likely that the larvæ had wandered from near-by leguminous plants. In Tennessee the writer did not succeed in rearing a single individual from egg to adult from any member of the grass family. Vigorous, newly hatched larvæ were offered barley, rye, Johnson grass (*Sorghum halepense*), and orchard grass (*Dactylis glomerata*) and refused them entirely. Corn and crab-grass (*Syntherisma sanguinale*) were eaten to some extent, but no larvæ matured on them. The negative results thus obtained from experiments with larvæ on cereals and grasses scarcely warrant including them as food plants.

The full list of known host plants includes the following:

<i>Daucus carota</i>	Wild carrot.
<i>Fragaria virginiana</i>	Virginia strawberry.
<i>Lespedeza procumbens</i>	
<i>Medicago sativa</i>	Alfalfa.
<i>Meibomia</i> sp.....	Tickweed.
<i>Melilotus alba</i>	White sweetclover.
<i>Phaseolus lunatus macrocarpus</i>	Lima bean.
<i>Pisum sativum</i>	Common pea.
<i>Potentilla canadensis</i>	Common cinquefoil.
<i>Rubus</i> sp.....	Blackberry.
<i>Salix</i> sp.....	Willow.
<i>Soja max</i>	Soybean.
<i>Stizolobium</i> sp.....	Velvetbean.
<i>Trifolium hybridum</i>	Alsike clover.
<i>Trifolium incarnatum</i>	Crimson clover.
<i>Trifolium pratense</i>	Red clover.
<i>Trifolium repens</i>	White clover.
<i>Vigna sinensis</i>	Cowpea.
<i>Vicia faba</i>	Broadbean.
<i>Vicia sativa</i>	Common vetch.

DESCRIPTION OF STAGES

THE ADULT

The moth (fig. 2) is dark brown and of moderate size, with wing expanse of about $1\frac{1}{4}$ inches. When at rest it resembles in outline an isosceles triangle with base slightly shorter than height. The sexes are easily distinguished by salient characters. The male is somewhat larger than the female, and more uniformly dark in color; the eyes and palpi are conspicuously larger; the antennæ are fringed their entire length with setæ much more numerous and longer than those found on

the female antennæ; and the frenulum on the male wings consists of one long, strong spine, as compared with two small, diverging spines on the female. (See fig. 3.)

The technical description of the adult by Smith (11) follows:

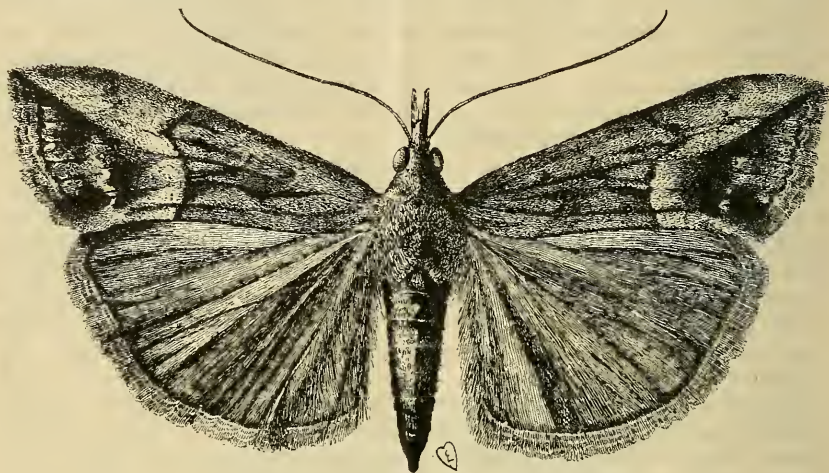


FIG. 2.—Adult of the green clover worm. Enlarged

Ground color a dark purplish or smoky brown. Head and thorax concolorous. Abdomen more smoky, like the secondaries. Primaries dusky to the transverse posterior line, then with bluish powderings, which scarcely relieve the somber tint in the male, but are quite contrasting in the female. In the latter sex the inferior half of the median space often becomes shaded with yellowish red-brown, sometimes quite contrastingly.

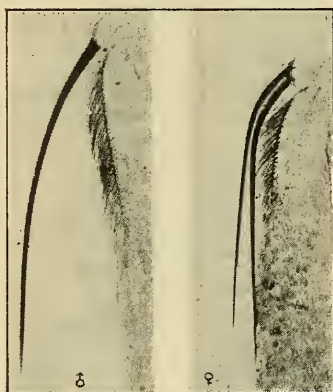


FIG. 3.—Frenulum of moth of green clover worm: Left, male; right, female. Much enlarged

Transverse anterior line red-brown, preceded by pale in the best marked specimens, outwardly bent, with three long outward angulations, rarely complete, and in the male quite frequently entirely obsolete. Transverse posterior line black or brown, outwardly bent over the cell and almost rigid beneath. The line is marked through the lower part of its course by elevated scales, which are most prominent on the inner margin. Subterminal line interrupted, pale, preceded by black spots, rather evenly bisinuate, often quite contrasting in the female, and as inconspicuous in the male. A brown terminal line, which is rarely interrupted, preceded by undefined bluish lunules in the interspaces. In the male the apex is blue powdered, the terminal space else quite even. In the female the apical patch is more contrasting, inferiorly limited by a blackish streak, the terminal space being irregularly and variably mottled with bluish brown and black. Opposite the hind angle is a longitudinal black mark, which crosses the subterminal line. Usually a narrow black line connects the median lines in the submedian interspace, and another connects the ordinary spots, which are much reduced and marked by black elevated scales. The basal space is also sometimes blue powdered or inferiorly brown. In the male the ordinary spots are sometimes hardly evident. Secondaries deep smoky-brown, varying a little in tinge toward brown or black. Beneath, uniformly brown or blackish; the secondaries with a more or less evident discal spot.

Expanse of wings, 27 to 34 mm.=1.10 to 1.35 inches.

THE EGG (FIG. 4)

Width 0.510 millimeter, height 0.346 millimeter. Subglobose, flattened, circular at the equator, with polar axis about two-thirds length of diameter; 14 to 16 prominent, acute, longitudinal ridges running from base to apex, each alternate one slightly longer; interspaces concave and crossed by fine, transverse, regularly placed ridges; polar area sculptured by a few fine ridges; base flattened and taking impression of surface to which attached. Color when laid shiny pale green, sometimes distinctly bluish-green; partly developed eggs with pale orange spots and streaks scattered over upper surface, and in eggs still further advanced with orange spots turned to distinct, sparsely distributed, reddish brown spots. Shortly before hatching the egg turns a dark metallic purplish-gray color. The empty shell is colorless, transparent, and iridescent.



FIG. 4.—Egg of green clover worm. Enlarged

THE LARVA (FIG. 5)

First instar.—Length 1.5 to 4 millimeters, head width 0.265 to 0.285 millimeter. The newly hatched larva is slender and much constricted between segments. Head considerably wider than body; shiny, transparent, with faint yellow tinge. Body translucent grayish-white,

with alimentary canal slightly darker. As the larva develops the body becomes faintly yellowish, usually tinged with green from chlorophyll in the alimentary canal. Throughout this instar the first three abdominal segments are considerably larger than the others; the next four are about equal in size; the eighth, of the same width, is considerably longer; the ninth is shorter and narrower than any except the tenth and last, which is still shorter. The constrictions are deepest between the first four abdominal segments. Prolegs on the third and fourth segments rudimentary, those on fifth, sixth, and last functional. Head oblique, somewhat flattened, pale, shiny, transparent, yellowish, tinged with green, caudal edge dark. Numerous



FIG. 5.—Photograph showing a comparison of the six larval instars of the green clover worm. Enlarged

short setae are scattered over the face, with one long one on either side of frons. Setae for the most part dark and moderately long, borne on small chitinizations slightly darker than surrounding tissues.

Second instar.—Length 3.5 to 7.5 millimeters, head width 0.353 to 0.459 millimeter. As compared with the first instar, the first three abdominal segments are not so distinctly larger than the rest, the constrictions between the segments are less deep, and the rudimentary prolegs of the third abdominal segment are less apparent, while those on the fourth have become functional. Body tubercles nearly circular, slightly elevated, and same color as surrounding tissue; setae fine, long, and pale.

Third instar.—Length 8 to 11 millimeters, head width 0.635 to 0.753 millimeter. Abdomen tapering slightly to caudal extremity, with constrictions between segments moderately deep. Prolegs on fourth, fifth, and last abdominal segments functional. At the second molt the vestigial prolegs on the third abdominal segment entirely disappear. Body chitinizations more elevated than in previous instar, otherwise the same. Setæ for the most part long and black. Body shiny yellowish-green, dorsal vessel darker green, accentuated by a faintly whitish-mottled border, a narrow mottled whitish stripe on a line just outside the posterior dorsal chitinizations, and another through the spiracles. These white stripes are not found on all larvæ in this instar, as individuals vary in this respect.

Fourth instar.—Length 11 to 19 millimeters, head width 0.886 to 1.166 millimeters. Body tapering gradually from sixth to caudal segments, moderately constricted between segments. Body shiny yellowish-green, with dark green middorsal line bordered on each side by a mottled whitish line, the narrow subdorsal stripe along the outside margin of posterior dorsal chitinizations more distinct than in preceding instar, and the lateral stripe on a line with spiracles wider, and more distinct than the others. Spiracles appearing as small white dots, those on prothorax larger and showing a fine dark edge.

Fifth instar.—Length 16 to 23 millimeters, head width 1.306 to 1.586 millimeters. Body widest along first three abdominal segments, tapering slightly toward each extremity. Constrictions between segments less pronounced than in previous instars, and the three pairs of longitudinal white stripes more distinct, though varying with individuals, head and body otherwise the same. Setæ for the most part moderately long and dark. Spiracles small, oval, white, with dark edges.

Sixth instar.—Length 18 to 31 millimeters, head width 1.866 to 2.052 millimeters. Body with first four abdominal segments nearly uniform in width, thence tapering gradually toward each extremity. Constrictions between

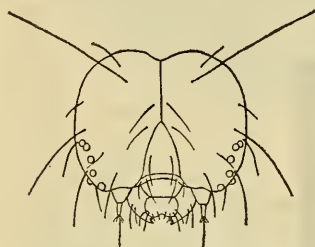


FIG. 6.—Dorsal view of head of larva of green clover worm

segments slight. Prolegs functional on fourth, fifth, sixth, and last abdominal segments, pedal hooks 17 to 24. Head (fig. 6) subspherical, flattened, oblique, with emargination at vertex moderately deep; pale yellowish-green, tips of mandibles dark, ocelli black, labrum and outer edge of mandibles distinctly whitish; face sparsely setose with a conspicuously long seta near middle of each side of epicranium. Mandible (fig. 7) short and stout, with three distal teeth and one broad cutting projection on inside. Cervical shield with convexity caudad, bearing four long, dark setæ inclined cephalad along cephalic margin and four smaller ones along caudal margin (fig. 8, TI, 1a, 1b, 2a, 2b). Prothoracic spiracle near caudal margin of segment, oval, white, with dark edge,



FIG. 7.—Mandible of larva of green clover worm

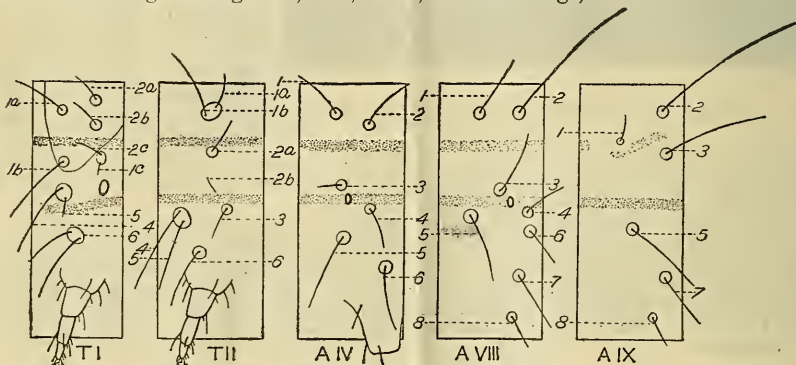


FIG. 8.—Setal maps of first and second thoracic and fourth, eighth, and ninth abdominal segments of larva of green clover worm: TI, Prothorax; TII, mesothorax; AIV, fourth abdominal segment; AVIII, eighth abdominal segment; AIX, ninth abdominal segment

Three oval, slightly elevated bisetose chitinizations are grouped around it, one dorsad, one cephalad, and one ventro-cephalad, all concolorous with surrounding tissue except at immediate bases of setæ (fig. 8, TI). Mesothorax and metathorax with one pair of bisetose chitinizations on dorsum, and on latus three unisetose and one bisetose chitinizations (fig. 8, TII), and one fine pale seta (2b) half way between setæ 2a and 3. On each of the first six abdominal segments there are six pairs of unisetose chitinizations, two on dorsum, bearing setæ 1 and 2, and four on latus, bearing setæ 3, 4, 5, and 6 (fig. 8, AIV); the three lateral chitinizations, bearing setæ 3, 4, and 5, form points of a triangle with the cephalic side longest and on a line with the spiracles, chitinization bearing seta 6 close to venter. Eighth abdominal segment (fig. 8, VIII) with setæ 1 and 2 nearly in alignment with each other, two setæ (4 and 6) caudo-ventrad of spiracle, seta 5 more dorsad than on the other segments, and setæ 7 and 8 on ventrum; ninth abdominal segment (fig. 8, AIX) with setæ 1, 2, and 3 forming nearly an equilateral triangle, setæ 4 and 6 missing, and setæ 7 and 8 nearly as on the eighth abdominal segment; all chitinizations nearly circular, slightly elevated, and of the same color as the surrounding tissue except for dark areas surrounding the immediate bases of the setæ. Setæ moderately long and dark. Abdominal spiracles oval, white, with dark rims. Body with a distinct white lateral stripe through spiracles, a narrow whitish subdorsal stripe along outer edge of posterior dorsal chitinizations, less distinct than in preceding instar, and the dorsal vessel dark green with paler green tissue on either side.

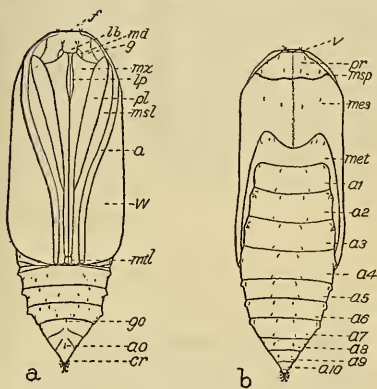


FIG. 9.—Pupa of the green clover worm: a, Ventral view; b, dorsal view. a, Antenna; a¹ to a¹⁰, abdominal segments of pupa; ao, anal opening; cr, cremaster; f, front; g, gena; go, genital opening; lb, labrum; lp, labial palpi; md, mandible; mes, mesothorax; met, metathorax; msl, mesothoracic leg; msp, mesothoracic spiracle; mzl, metathoracic leg; mx, maxilla; pl, prothoracic leg; pr, prothorax; v, vertex; w, mesothoracic wing.

PREPUPAL STAGE

The body is considerably shorter than that of the full-grown larva, and in natural position remains slightly curved. It is robust with greatest width near middle, but tapers rather sharply toward caudal extremity; the head and prothorax are nearly the same width; the mesothorax is wider and the longest

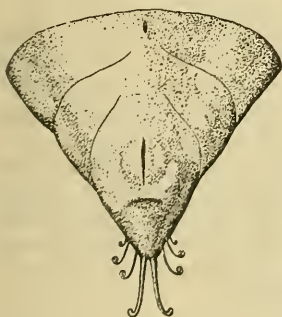


FIG. 10.—Caudal end of female pupa of the green clover worm. Enlarged

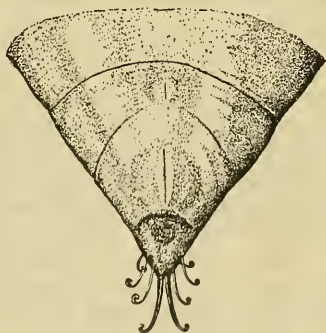


FIG. 11.—Caudal end of male pupa of the green clover worm. Enlarged

segment in the body. General color pale green with a dark green middorsal stripe, and a similar though slightly broader lateral stripe running on a line just dorsad of spiracles. Longitudinal white markings entirely lacking; ocelli no longer black but concolorous with face; spiracles transversely oval, white in color, edged with brown. Pedal extremities retracted, leaving skin loose. As pupation approaches, the body becomes sufficiently contracted to leave the skin around the caudal extremity wrinkled.

THE PUPA (FIG. 9)

Length of female 11 to 13 millimeters, average 12.17 millimeters; male 12 to 15 millimeters, average 13.71 millimeters. Width about 4.5 millimeters. Body subcylindrical, with abdomen acute. Two pairs of minute setæ on front and other minute setæ sparsely distributed over rest of body. Cremaster with two stout spines bluntly curved at extremities, and on each side near their bases three smaller setæ curved and thickened at extremities. The spiracles are transverse openings on tubercular prominences. In the female (fig. 10) the genital opening is nearer the caudal margin of the seventh abdominal segment than in the male (fig. 11). Surface of wing sheaths and prothoracic and mesothoracic regions coarsely rugose. Dorsum of abdominal segments coarsely punctate, ventrum sparsely punctate; caudal border of each abdominal segment smooth. The pupa is pale yellowish-green when first formed but soon turns chestnut-brown to fuscous, shiny, and sometimes almost black before emergence occurs.

LIFE HISTORY AND HABITS

ADULT STAGE

EMERGENCE

When the moth emerges, the pupal skin is broken along the sutures of the head and thorax. One moth, after detaching itself from the case, was observed to crawl rapidly away, coming to a standstill with head upward on the stem of an alfalfa plant on which it was allowed to crawl. Its wings, which were at first short, attained full growth in the course of eight minutes.

HABITS IN THE FIELD

During the day the moths stay in hiding on the under side of leaves or grass blades, sometimes in tree tops, and frequently under the eaves and on the walls of barns and houses, where their dark color enables them to escape notice. At dusk they become active and in warm weather may be observed in the fields feeding on the nectar of the blossoms of their host plants and flitting from plant to plant. Their flight is zigzag and undulating, and on alighting they quickly dart to the under side of the leaf or other object. If pursued they frequently fly much higher than housetops and to a distance of some 50 to 100 yards away before alighting.

In broad daylight they are not easily aroused; but at dusk they are very timid, flying up at the slightest disturbance. When suddenly frightened, they often feign death and drop to the ground with wings folded; but after an interval, if undisturbed, they crawl rapidly along the ground and fly up when well out of danger.

In order to find shelter for hibernation they collect on barns and haystacks, where they are most often found during late fall, winter, and early spring. They are active throughout the year, except when the weather is extremely cold, and Chittenden (2) records one flying at a temperature as low as 51° F. Both male and female moths have been found to be attracted by lights.

OVIPOSITION

When ovipositing the moth partially raises her body and, while slightly retracting and extending her ovipositor, curves the end of her abdomen downward, its tip almost touching the surface on which she rests. After several minutes in this attitude, a single egg is quickly deposited. She then moves on to another resting place,

and in this manner locates the eggs, one at a time, on the foliage of the food plant. In alfalfa and clover fields the writer has found the eggs nearly always on the under side of the foliage to the number usually of one, and never more than four on a leaflet.

In order that data might be procured as to the number of eggs the female of this species usually lays in the course of her life, individuals were captured in the field and confined for the most part in vials provided with fresh leaves of food plants and bits of moist blotting paper. Table 1 shows egg records of 24 of these moths. The maximum number of eggs laid by a single female was 670. Moths captured by the writer late in the fall refused to oviposit.

TABLE 1.—*Data on oviposition and longevity of moths of the green clover worm captured in the field, 1916*

No.	Date of capture	Date first egg was laid	Date last egg was laid	Length of oviposition period	Number of eggs laid	Date of death	Length of life in captivity
				Days			Days
1.....	Mar. 25	Mar. 26	Apr. 4	9	175	Apr. 5	11
2.....	30	Apr. 1	12	11	270	13	14
3.....	30	1	3	2	60	4	5
4.....	Apr. 3	4	9	5	216	10	7
5.....	3	4	10	6	125	11	8
6.....	3	5	10	5	98	10	7
7.....	3	5	12	7	198	15	12
8.....	3	4	8	4	155	10	7
9.....	7	13	21	8	266	23	16
10.....	7	8	18	10	120	23	16
11.....	12	15	16	1	114	16	4
12.....	12	15	16	1	135	17	5
13.....	12	13	22	9	227	23	11
14.....	18	19	21	2	107	22	4
15.....	July 25	July 25-26	July 26	1	121	July 27	2
16.....	25	25-26	27	1	212	29	4
17.....	25	25-26	31	5	300	Aug. 1	7
18.....	25	25-26	28	2	153	July 28	3
19.....	25	25-26	27	1	224	28	3
20.....	25	25-26	Aug. 1	6	137	Aug. 1	7
21.....	25	25-26	4	9	670	6	12
22.....	25	26-27	3	7	193	6	12
23.....	25	25-26	3	8	345	6	12
24.....	25	25-26	July 26	1	208	29	4

The oviposition period may last 11 days or more, and during the spring and summer months extends throughout most of the life of the adult.

It was observed that moths kept in captivity would seldom deposit large batches of eggs on consecutive days, but would rest from egg laying for a day or two after such exertions. One female oviposited on consecutive days, as follows: 168, 8, 159, 83, 0, 0, 161, 0, 60, 31; another: 119, 40, 59, 0, 0, 11, 0, 110, 6. The greatest number of eggs laid during any one period of 24 hours was 208.

LONGEVITY OF ADULT

Table 1 shows the length of life of 24 females captured in the field during the spring and summer months. It will be observed that the longest time any individual lived was 16 days. As a check on this record, which includes only moths captured in the field, a few records were obtained from adults reared in confinement. Table 2 shows the results obtained. The average length of life in this experiment came

to 7 days. During the winter the life of the moth is greatly extended, because of hibernation.

TABLE 2.—*Longevity of moths of the green clover worm reared in confinement*

No	Sex	Date of emergence	Date of death	Length of life
				<i>Days</i>
1.....	Female.....	Oct. 14	Oct. 22	8
2.....	Male.....	18	25	7
3.....	Female.....	16	25	9
4.....	Female.....	28	Nov. 2	5
Extremes.....				5 and 9
Average.....				7.25

EGG STAGE

Table 3 shows the length of the period of incubation of eggs laid by moths in captivity. During the summer and early fall months eggs hatched in from 2 to 5 days, but during cool weather in the spring the incubation period was lengthened to as many as 14 days.

TABLE 3.—*Length of incubation period of eggs of the green clover worm*

Egg lot No. ¹	Laid—	Hatched—	Incuba- tion	Egg lot No.	Laid—	Hatched—	Incuba- tion
	1916	1916	<i>Days</i>		1916	1916	<i>Days</i>
1.....	Mar. 26	Apr. 2	7	19.....	Apr. 20	May 1	11
2.....	27	4	8	20.....	22	1	9
3.....	28	4	7				
4.....		13	14	Spring average.....			9.45
5.....	Apr. 1	13	12				
6.....	2	14	12	1.....	July 26	July 31	5
7.....	3	14	11	2.....	27	Aug. 1	5
8.....	4	15	11	3.....	28	1	4
9.....	5	15	10	4.....	Aug. 1	3	2
10.....	6	18	12	5.....	11	15	4
11.....	8	14	6	6.....	25	29	4
12.....	9	17	8				
13.....	13	22	9		1915	1915	
14.....	14	22	8	7.....	Sept. 8	Sept. 12	4
15.....	15	23	8	8.....	10	13	3
16.....	16	24	8	Summer and early fall average.....			3.88
17.....	17	26	9				
18.....	18	27	9				

¹ Each lot contained from 15 to 1,104 eggs.

LARVAL STAGE

GENERAL HABITS

In hatching, the larva eats a ragged hole at one side of the apex of the egg just large enough to permit exit. It then works its way slowly out and at once searches for food. During the first three instars the larva, when feeding on alfalfa, skeletonizes the leaf, leaving the upper epidermis intact; but beginning with the fourth instar it eats entirely through, avoiding only the larger veins. On large-leaved plants, such as soybean, the larvæ are usually found stretched out on the under side of a leaflet; but on plants with smaller foliage they commonly feed extended along the stem, and in these positions their color blends

with the foliage and renders detection difficult. The injury resulting from the work of this caterpillar is of a scattered character, giving the field a ragged appearance. Figure 12 shows a soybean leaf eaten in a characteristic manner. This distribution of injury may partly be accounted for by the readiness with which the larvæ leap off a plant even when slightly disturbed. The larvæ, most noticeably the young ones, have the habit when molested of sharply bending their bodies somewhat like a jackknife instead of coiling them.

QUANTITIES OF FOOD EATEN

In order to ascertain the quantity of foliage eaten by a single caterpillar in the course of its life, a series of larvæ were supplied with measured quantities of cowpea and alfalfa leaf, and it was found that the average larva consumed foliage equivalent to about 19 average-sized leaflets of alfalfa. Table 4 shows the average quantity eaten by each of five larvæ during the first five instars, and by each of four during the sixth.

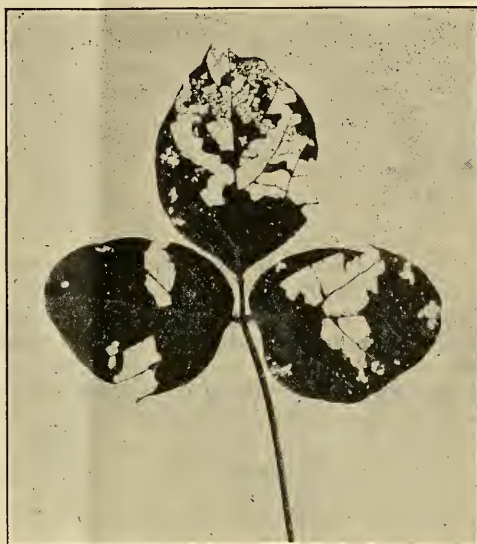


FIG. 12.—Soybean leaf eaten in characteristic manner by the green clover worm

TABLE 4.—Quantity of foliage eaten by larvæ of the green clover worm

Instar	Square millimeters
First.....	3.9
Second.....	34
Third.....	84
Fourth.....	117
Fifth.....	624
Sixth.....	1,660
Total.....	2,522.9

LARVAL DEVELOPMENT

The larva molts five times in the course of its development, although in exceptional instances individuals have been observed to undergo six molts. Table 5 shows the length of the instars from records of 33 larvæ reared during summer and fall seasons in Tennessee. The rearings were conducted in an outdoor insectary under conditions and temperatures approximating the natural environment. The average length of the larval period came to 22.84 days.

TABLE 5.—Lengths of larval instars of the green clover worm

Instar	Number reared	Instar lengths		
		Maximum	Minimum	Average
		<i>Days</i>	<i>Days</i>	<i>Days</i>
First.....	33	4	2	3.09
Second.....	33	4	2	2.21
Third.....	33	3	2	2.36
Fourth.....	33	5	2	3.27
Fifth.....	33	6	2	3.64
Sixth.....	33	14	5	8.27
Total.....				22.84

In the course of the larva's growth the size of its head increased with each molt but remained constant throughout each instar, thus forming a reasonably safe guide for determining the instar. Table 6 gives the head widths by instars from numerous measurements.

TABLE 6.—Head widths of green clover worm larvæ at different stages of growth

Instar	Number measured	Width		
		Maximum	Minimum	Average
		<i>Millimeters</i>	<i>Millimeters</i>	<i>Millimeters</i>
First.....	6	0.285	0.265	0.268
Second.....	6	.459	.353	.403
Third.....	10	.753	.635	.713
Fourth.....	11	1.166	.886	.996
Fifth.....	11	1.586	1.306	1.454
Sixth.....	5	2.052	1.866	1.940

The measurement of the length of the caterpillar can also be used to some extent to indicate the instar, although the degree of individual variation in length is much greater than for the head width. Table 7 may be used as a guide in this respect.

TABLE 7.—Larval lengths of the green clover worm at different stages of growth

Instar	Maximum	Minimum	Length of larva	
			Average at end of instar	Average at beginning of instar
	<i>Millimeters</i>	<i>Millimeters</i>	<i>Millimeters</i>	<i>Millimeters</i>
First.....	4.0	1.5	3.58	1.50
Second.....	7.5	3.5	6.55	3.58
Third.....	11.0	8.0	10.17	6.55
Fourth.....	19.0	11.0	15.59	10.17
Fifth.....	23.0	16.0	20.68	15.59
Sixth.....	31.0	18.0	28.60	20.68

RESISTANCE TO FROST

The larvæ of *Plathypena scabra* are known to survive ordinary frosts, but eventually succumb to continued cold weather. None have been found alive in the field in the vicinity of Nashville, Tenn., later than October 18. W. R. McConnell reported finding numerous live larvæ in a plot of soybeans at Greenwood, Miss., as late as

October 29. On November 14, however, many of them were observed to be dead on the outer leaves, having been killed by heavy frosts that occurred during the preceding three nights, although a few larvæ were still alive in protected places. Subsequently no living larvæ were to be found, and their disappearance was attributed to the cold weather. At Nashville, Tenn., eight healthy larvæ were placed in the field on an alfalfa plant, under a wire cage, and a thermograph was installed near by. A minimum temperature of 34° F. killed three of these larvæ the first night. The next night two more succumbed to a temperature of 31° F., but the remaining three survived a temperature of 26° F. and two of them eventually pupated, one later emerging as a moth.

PREPUPAL STAGE

When mature, the larva stops feeding, descends to the earth, and on or partly beneath the surface thereof constructs an oval cocoon (fig. 13) of earthen particles or bits of rubbish and leaves loosely webbed together. If no débris be present, plain silken cases are spun, protected on one side by some object. Within the cocoon the larva lies at first in a curved position, which gradually becomes less pronounced as the body contracts. This period lasts from one to six days, with an average of about two days in warm weather.

PUPAL STAGE

The pupal stage ordinarily covers a period of from 7 to 24 days, as shown in Table 8, data for which were obtained from 20 pupæ reared from May

20 to November 3. There is evidence, however, that this species sometimes hibernates as a pupa. From a number of pupæ formed between October 8 and 19 and exposed to outdoor conditions, the moths failed to emerge at the usual time; but when these were brought indoors late in November one adult emerged, having



FIG. 13.—Cocoons with pupæ of the green clover worm partly out of them

passed a pupal period of 42 days, and another came out December 2 after a pupal period of 44 days.

TABLE 8.—*Length of pupal stage of the green clover worm*¹

No.	Date of pupation	Date of emergence	Number of days	No.	Date of pupation	Date of emergence	Number of days
1	May 20	May 30	10	13	Aug. 12	Aug. 24	12
2	do	May 31	11	14	Aug. 14	Aug. 23	9
3	June 19	June 27	8	15	Aug. 25	Sept. 8	14
4	do	June 28	9	16	Sept. 1	Sept. 15	14
5	June 22	June 29	7	17	do	Sept. 21	20
6	do	June 30	8	18	Oct. 4	Oct. 28	24
7	June 23	July 1	8	19	Oct. 6	Oct. 29	23
8	July 1	July 10	9	20	Oct. 14	Nov. 3	20
9	do	July 12	11				
10	July 2	do	10		Average		12.1
11	July 5	do	7		Maximum		24
12	do	July 13	8		Minimum		7

¹ The data for the months of June and July were obtained by F. M. Moody.

SUMMARY OF LIFE CYCLE

The egg-laying period of the moth may last for a period of 11 days or more, the egg hatching during the summer and early fall in about 4 days. The larval period lasts about 23 days, in the course of which the caterpillar molts five times and spends approximately two days as a prepupa inside the cocoon. The pupal period lasts from 7 to 24 days, except when lengthened by hibernation. Table 9 gives the average lengths of the different stages.

TABLE 9.—*Summary of duration of stages of development of the green clover worm*

Stage	Average period
Egg	Days 3.88
Larva	22.84
Pupa	12.10
Total	38.81

SEASONAL HISTORY

NUMBER OF GENERATIONS A YEAR

During the season of 1916 at Knoxville, Tenn., four distinct generations were found to occur. Certain heavily infested alfalfa fields on the farm of the State Agricultural Experiment Station were visited every few days, and records were kept of the varying abundance of the different stages of this species. Parts of these fields were standing throughout the season, which eliminated the interference of cutting with the development of the generations. Figure 14

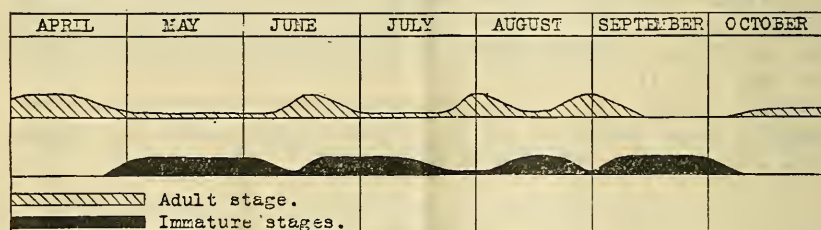


FIG. 14.—Diagram showing the number of generations of the green clover worm during the year 1916 at Knoxville, Tenn.

shows the periods of occurrence of the adult and immature stages, as found from April to October, inclusive. Adults in abundance were noted about the first of April and remained fairly numerous until the middle of that month. By April 27 young larvæ of the first generation appeared, and larvæ were found abundantly distributed over the fields throughout the month of May. In the interval the moths nearly disappeared, and only a few battered individuals could be found until about the middle of June, when freshly emerged moths began to appear in great numbers. During the middle and last of June young larvæ of the second generation became plentiful in the field and remained very numerous until the second week in July, by which time they had reached full growth and were pupating. By July 18 newly emerged moths from this second generation began to appear, and by July 24 they were found in great numbers in the field. The third generation of larvæ, resulting from eggs laid by these moths, were present in the field in abundance by the second week in August, and adults, although present in the field, were greatly diminished in numbers. During this time the weather was warm and the caterpillars were maturing rapidly. By August 22 practically all of these had pupated and newly emerged moths were becoming numerous. Young larvæ of the fourth generation were found about the 1st of September, but by the 12th only a few battered moths were present. Larvæ continued abundant throughout the remainder of the month. In October a few freshly emerged adults were collected.

According to certain authors (4, 10), the number of generations is fewer farther north, decreasing to three and even two per annum.

HIBERNATION

Observations indicate that hibernation takes place in both the pupa and adult stages. Although repeated attempts to carry the moths through the winter in cages failed, yet in the field at Nashville, Tenn., they were found numerous during October and part of November, and again during the first warm days of February. Philip Luginbill observed five moths flying in a woodshed at Columbia, S. C., on January 5. Chittenden (2) observed that "About the city of Washington this moth is one of our latest as well as earliest species, individuals occurring commonly in the writer's experience about the Department of Agriculture buildings throughout November, as late as the first week in December, and as early as March 10." Riley (9) reported a large number of these moths transmitted to Washington during the winter by correspondents who confused it with moths of the cotton leafworm (*Aletia*) *Alabama argillacea* Hbn.

As stated in the discussion of the pupal stage, pupæ formed late in the fall at Knoxville, Tenn., failed to produce adults until brought into the heated laboratory. If left in the field, they might have passed the winter in this stage. One pupa in an outdoor cage remained alive as late as December 22. In this connection it might be mentioned that Riley (9) stated that pupæ were found in Missouri throughout the winter.

NATURAL ENEMIES

Ten species of parasites were reared from *Plathypena scabra* collected in Tennessee, and 18 more have been reported from other localities. Fourteen of these are Hymenoptera and 14 Diptera. Predators and fungi were also found to attack this insect extensively.

HYMENOPTERA.

Apanteles harnedi Vier.³ was reared by the writer from larvæ collected at Nashville and Knoxville, Tenn., in the years 1914, 1915, and 1916, and by C. L. Scott at Brownsville, Tex., March 30, 1913.

A campoplegine, probably a new species and new genus, was recorded by Sherman (10) as reared in North Carolina.

Euplectrus comstockii How. was reported by C. N. Ainslie as very commonly parasitizing *Plathypena scabra* in the vicinity of Elk Point, S. Dak.

Euplectrus plathypenae How. was reared from this host at Washington, D. C., on July 11, 1882, from material collected in that vicinity, and was described by Howard (6) who named it after the genus *Plathypena*.

Hemiteles sp.⁴ was reared by P. Luginhill at LaFayette, Ind., April 2, 1912.

Meteorus sp.; one specimen⁵ was reared by the writer at Nashville, Tenn., in 1915.

Mesochorus sp.; a single specimen⁵ was reared by the writer at Nashville, Tenn., in 1915.

Microgaster facetosa Weed⁶ was reared from this host at Knoxville and Nashville, Tenn., by the writer, and at Hagerstown, Md., by H. L. Parker (8).

Microplitis varicolor Vier. was reared from this host at Columbia, S. C., by R. J. Kewley, and by the writer at Nashville, Tenn. (8).

Rhogas canadensis Cress.; a single specimen⁷ was reared from *Plathypena scabra* by Philip Luginbill at LaFayette, Ind., in 1911.

(*Rhogas*) *Aleiodes intermedius* Cress. was reported by Hawley (4) as reared from a *P. scabra* larva collected in New York.

Rhogas nolophanae Ashm.⁸ was the most common parasite at Nashville, Tenn., in 1914. It was reared from larvæ collected in the spring, the adults first appearing about the 20th of May. The cocoon is yellowish-brown, slender, from 8 to 10 millimeters long by 1.75 millimeters wide, and formed from the shrunken and stiffened skin of the caterpillar. Not more than one individual was reared from a single host. Six specimens each passed eight days in the cocoon. The exit hole is made on the dorsum in the vicinity of the sixth and seventh abdominal segments.

Rhyssalus loxoteniae Ashm. was reported by Hawley (4) as reared from a larva of this insect collected in New York.

Trichogramma pretiosa Riley was recorded by Sherman (10) as being a very common parasite of the egg in North Carolina.

³ Four specimens reared in Tennessee determined by A. B. Gahan.

⁴ One specimen determined by H. L. Viereck.

⁵ Determined by A. B. Gahan.

⁶ Eleven specimens from Knoxville, Tenn., determined by A. B. Gahan.

⁷ Determined by H. L. Viereck.

⁸ Nine specimens determined by A. B. Gahan.

DIPTERA

One male of *Compsilura concinnata* Meig. was reared from a *Plathypena scabra* pupa, the larva of which was collected at Indian Orchard, Mass., by D. A. Ricker. This tachinid was imported from Europe to aid in controlling the gipsy and brown-tail moths in New England and has proved a very effective enemy against them. It was first introduced in 1906, but the most satisfactory colonies were planted in 1909. It is known to parasitize a large number of hosts in Europe and has already been reared from a number of native hosts.

Exorista blanda O.S. is recorded by Chittenden (2) as having been reared from the pupa of *Plathypena scabra* September 7, 1899.

Exorista amplexa Coq.⁹ was reared from this host at Hagerstown, Md., by C. M. Packard in 1914.

Hypochaeta eudryae Smith¹⁰ was reared by the writer at Knoxville, Tenn., in 1916. Those observed emerged from the larva stage of the host and formed puparia about 5 millimeters long.

Hypochaeta longicornis Schiner¹¹ was reared by W. R. McConnell at Greenwood, Miss., September 9, 1913.

Phorocera flavicauda V. d. W.¹² was reared by E. H. Gibson at Greenwood, Miss., in 1913 and by the writer at Knoxville, Tenn., in 1916.

Phorocera claripennis Macq.¹¹ was reared by W. E. Pennington from a larva collected at Hagerstown, Md. The host larva was collected June 21, 1915; the dipterous puparium was formed July 6; the dipterous adult emerged July 15.

Trichophora ruficauda V. d. W.¹³ was more abundant at Knoxville, Tenn., in 1916 than any other parasite reared from *Plathypena scabra*. Specimens of this tachinid were also reared by the writer at Nashville, Tenn., in 1915; and by E. H. Gibson at Greenwood, Miss., in 1913, F. M. Moody at Charleston, Mo., and R. W. Leiby at Terra Ceia, N. C. (10). The host caterpillars of specimens reared at Knoxville each showed a dark spot bearing a small round pore opening through the skin and through which in some cases the movements of the parasitic larva could be seen. On the pupation of the host this pore was retained and enlarged, and usually occurred between the second and fifth abdominal segments. The puparium as a rule was left inside the pupal skin, filling all but the tip of the abdomen. One which was protruding from the host when the latter was in the prepupal stage is shown in Figure 15.



FIG. 15.—Photograph showing a puparium of *Trichophora ruficauda* partially protruding from its host, a larva of the green clover worm

⁹ Determined by W. R. Walton.

¹⁰ Seven specimens determined by W. R. Walton.

¹¹ One specimen determined by W. R. Walton.

¹² Four specimens from Tennessee determined by W. R. Walton.

¹³ Sixteen specimens reared in Tennessee determined by W. R. Walton.

Winthemia quadripustulata Fab.¹⁴ was reared by F. M. Moody at Charleston, Mo., and by the writer at Knoxville, Tenn., in 1916. The caterpillars from which the latter were reared each bore two small, oval white eggs on its thorax; and, when swept from the field, one was a prepupa, while the other was still feeding. The former pupated a few days after capture, and when examined three days later a large puparium was found filling over two-thirds of its interior, leaving only the end of the abdomen empty. The other caterpillar also pupated; but in this case the parasite larva, a yellowish-white maggot 8 millimeters long, emerged from the pupa and formed its puparium outside.

In addition to the foregoing Diptera, Sherman (10) listed as reared in North Carolina the following five species:

Bombyliidae: *Anthrax lateralis* Say.

Tachinidae: *Euphorocera floridensis* Tns., *Exorista boarmiae* Coq., *Frontina aletiae* Riley.

Sarcophagidae: *Sarcophaga cimbicis* Tns.

HEMIPTERA

NABIDAE

Nabis ferus L.¹⁵—This slender gray bug has been found in the field at different times feeding on the young *Plathypena scabra*. As it has usually been found exceedingly abundant in infested fields in Tennessee examined by the writer, it undoubtedly aids considerably in the destruction of the caterpillars. The nymphs as early as the first and second instars have been observed to attack and kill the young arvæ. Bugs kept in captivity deposited eggs in rows along the stems of the alfalfa plants, each egg inserted deeply, with only one end showing on the surface as a tiny white spot.

PENTATOMIDAE

Podisus maculiventris Say, the spined soldier-bug, has been found numerous in infested fields and undoubtedly kills many of the caterpillars. One bug was found in the field with a *Plathypena scabra* larva pierced by its beak. This specimen was determined as *Podisus maculiventris* Say by O. Heidemann. Individuals kept in captivity fed readily on the caterpillars, one destroying five in the course of five days' captivity. It pierced the larva with its beak and sucked its contents, leaving only a shrunken remnant of skin and solid parts.

FUNGOUS DISEASE

In the fall of the year great numbers of larvæ are killed off by the fungus *Botrytis rileyi* Farl.¹⁶ Both at Knoxville and Nashville, Tenn., they have been severely attacked by this disease, and similar reports have come from Hagerstown, Md.

¹⁴ Three specimens from Tennessee determined by W. R. Walton.

¹⁵ An individual found by the writer feeding on a *Plathypena scabra* larva was identified by Herbert Osborn as *Nabis ferus* L.

¹⁶ Infestation on *Plathypena scabra* larvæ collected by the writer at Knoxville, Tenn., was determined as this fungus by Alden T. Speare.

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THE EFFECT OF WEATHER UPON THE CHANGE IN WEIGHT OF A COLONY OF BEES DURING THE HONEY FLOW

By JAMES I. HAMBLETON, *Apiculturist, in Charge of Bee Culture Investigations, Bureau of Entomology*

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INTRODUCTION

The annual honey crop of a colony of honeybees is dependent upon a considerable number of factors, part dealing with the activities of the bees and part resulting from the various external factors influencing the secretion of nectar by the honey plants of the locality. Demuth (8, p. 18)¹ has shown this interrelationship by pointing out that there are four factors which combine to make the honey crop: A surplus population in the colony over and above the bees necessary for colony maintenance, a predominance of the storing instinct and the control of swarming, honey plants growing under optimum conditions, and weather suitable for the secretion of nectar and the gathering of it by the bees. If any one of these factors is reduced to zero, the crop is zero, and if any one factor is reduced one-half, the crop is one-half the maximum. Naturally, so long as the factors do not rest on a mathematical expression, it is impossible to interpret them with exactness, but every experienced beekeeper realizes this interrelationship; it is therefore safe, as a working hypothesis, to accept these factors as real and fundamental.

Most of the work done on beekeeping subjects has dealt either with methods of obtaining for the colony a surplus population at the right time for the gathering of the crop, or with the management of

¹ Reference is made by number (italic) to "Literature cited," p. 50.

the colonies so as to induce the bees to expend their energy in gathering, which, as every experienced beekeeper knows, means the control of swarming and any other instinctive activity which might tend to reduce the manifestation of the gathering instinct. The last two factors of those above mentioned have to a considerable degree been neglected, doubtless because they are outside the control of the beekeeper in any given location. Since the honey crop is so intimately connected with these factors, however, it is unwise to neglect them. There are extensive records and lists of the plants which furnish nectar in quantities sufficient to make beekeeping profitable in the various parts of the country, and there are certain results of botanical investigations which bear on this subject, but as a rule these results have not been part of the beekeeping literature. Almost no attention has been paid to the effect of weather factors on the gathering of the crop.

The purpose of this bulletin is to present information on the relationship existing between changes in the weight of a colony of bees during a honey flow and the prevailing weather conditions, based on data obtained at the Bee Culture Laboratory, Somerset, Md., from February to November, 1922, and for the month of May, 1923. The major problem during this time was an intensive study of colony temperatures, but this experiment necessitated the recording of changes in the weight of at least one colony of bees hourly throughout the day and night for long consecutive periods. At the conclusion of the experiment a hasty survey of these changes immediately revealed an abundance of interesting data which seemed to throw considerable light upon the relationship of changes in hive weights to outside conditions. Although the data herein recorded on the factors influencing changes in weight are not as complete as they should be to carry such a problem to a final conclusion, the subject is here presented from the material available in the hope that it will serve as a stimulus to investigators in different great honey-producing areas to study the relationship of weather to honey production. A problem like this can not be solved without such comparative data. Information of this sort covering the principal honey-producing sections of the United States would be of inestimable value in the furtherance of beekeeping. A knowledge of existing honey flora and a correlation of weather conditions with bee behavior should help the prospective beekeeper in choosing the best beekeeping locality. At the present time there is no method of predicting whether a locality will prove profitable to the beekeeper except by the results obtained by other beekeepers. It would be well to know just why certain plants produce nectar in one locality and not in another, and, more important still, to discover if possible the laws underlying the relationship between bees, nectar-producing plants, and weather conditions as they influence the results of the beekeeper, and to determine, if possible, which are the most important factors upon which the honey crop depends.

In this discussion the results of the relationship of bees and nectar-producing plants are shown either as surplus honey or as increase in the weight of the colony. The two results are inseparable as far as the present work is concerned. No effort was made to study plant behavior and bee behavior as separate subjects, but the results

of the two working together as one, and recorded as "colony weight changes," have been studied in their relation to the prevailing weather conditions.

It is a very common practice among the best beekeepers to maintain what is known as a scale colony. A colony of average strength is usually chosen for this purpose and is placed on scales in the apiary. This colony is weighed once or twice a day, usually in early morning and after the bees have stopped flying in the evening. Such weighings however, are usually made in a haphazard manner, without much care that the weighings are recorded at an exact time each day. Such records give little information except that they indicate in a rough manner the trend of the honey flow. Unfortunately, even such records as these are not available for most localities.

Records of careful hourly weighings of colonies are scarce. Dufour (10) pointed out the value of hourly weighings and showed how enormously the hourly changes in weights throughout the day may vary on days showing the same net gain. Figure 1, taken from data used in the present investigation, illustrates graphically the activities on two days when the net gains were approximately the same. The times of regaining the original weights are shown at the intersections of the curves with the zero line. Dufour (10) gives information on the weather conditions only in a general

way, during the time when he carried on his experiments, and it is therefore impossible to calculate the exact relationship in his investigation between the changes of colony weight and the weather.

In any discussion of changes in colony weight it is important to keep in mind the fact that these changes are brought about by two factors working jointly, both influenced by weather conditions. These factors are the secretion of nectar by the plants and its collection by the bees. Of the two factors, investigators have given more attention to nectar secretion than they have to bee behavior. Even in the field of nectar secretion there is no general agreement as to the

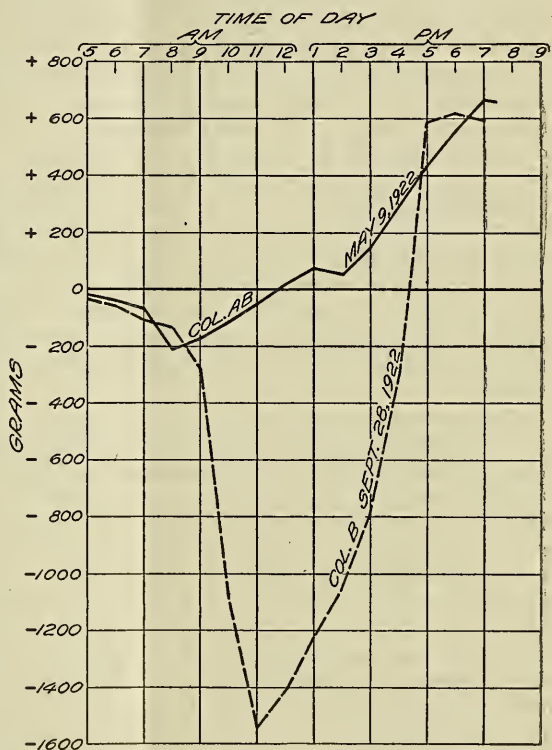


FIG. 1.—Graphs of hourly changes in the weight of a colony of bees on two days when the net gains were approximately the same. The solid line presents the changes on May 9, the other those on September 28, 1922

relative value of the influencing factors; certainly none based on a mathematical determination of their relative importance.

Kenyon (21) and Kenoyer (20) called attention to Dufour's work in the hope that others would carry on similar experiments, but no extensive research seems to have been undertaken until the present work. Discussions of factors influencing nectar secretion alone are often somewhat misleading to the beekeeper, because factors which may stimulate or retard nectar secretion may not be apparent at the hive as shown by changes in weight or in the honey crop.

Considerable work has been done on the problem of nectar secretion and the influence upon it of temperature, humidity, altitude, latitude, and similar factors, but little is on record other than casual observations by beekeepers as to the influence of these factors on bee behavior during the active season, either in or out of the hive. The works on nectar secretion by Bonnier, Behrens, deLayens, and Kenoyer stand out prominently in this line. These writers and others have made important contributions on the mechanism of nectar secretion and on the factors influencing it. Unfortunately, only a comparatively few plants have been studied for nectar secretion from a physiological point of view, and when thus studied the number of individuals of a species has of necessity been small. Too often observations have been confined to flowers cut from the plant in order to control the governing factors, such as temperature and humidity, thus leading to erroneous conclusions. Loftfield (22, p. 101) has pointed out in the study of stomatal movement the great difference in behavior between cut stems and potted or field plants of the same species.

It is quite evident that the factors influencing nectar secretion are not necessarily synonymous with those affecting the changes in weight of a colony of bees during the honey flow. In glancing over papers dealing with nectar secretion there is usually no clear distinction drawn between the amount of nectar secreted and the surplus honey gathered by bees, and one might assume that what affects one should affect the other in like manner. This appears not to be the case, as indicated by the data at hand. It is also evident that data on nectar secretion for certain species of plants should be limited largely to the species in question and not used for comparison with other species in other localities. If climatic conditions affect the behavior of bees in the same manner as they affect nectar secretion, one would expect to find a close correlation between factors reputed to be favorable both to nectar secretion and to increases in the weight of colonies of bees, but such a correlation does not seem to exist. It seems, therefore, either that the proper combination of factors influencing nectar secretion has not been discovered, or that the effect of weather conditions upon the behavior of bees is entirely different from their effect upon plants. It has previously been impossible to determine by judging from the changes in the weight of a colony of bees whether weather conditions influence the more greatly bee behavior or nectar secretion; and, from the standpoint of the practical beekeeper, the influence of weather upon colony weight is far more important than its influence upon either nectar secretion or bee behavior alone.

METHOD OF OBTAINING DATA

From February to November, 1922, continuous records were made of a colony of bees placed on platform scales sensitive to 10 grams. Owing to the nature of the principal problem under investigation, hive temperatures, the hive was left unprotected and certain of the weight records were rendered useless, water remaining on the hive and bottom-board after rains causing too great errors in the weight records. During most of the month of June, 1922, alterations were necessary in the apparatus for recording temperatures in this colony, and weight records are therefore not available for this month.

A standard 10-frame Langstroth hive was used to house this colony. Previous to the honey flow two brood chambers were in use, and a few days before the beginning of the honey flow the colony was manipulated to prevent swarming and additional supers were added. The colony was left in this condition until, in June, alterations were made in the temperature-recording apparatus.

During May, 1923, two colonies placed side by side, both on equally sensitive scales, were observed for additional data covering another honey flow. Both colonies were in standard 10-frame hives, each having two hive bodies for brood and three, above a queen excluder, as supers. In this case the colonies were given ample room for brood rearing and storage of nectar, and made no attempt to swarm. Precautions were taken to shield these hives from rain, by placing a sloping board over the entrance of each colony in such a manner that rain would not fall on the bottom-board, while there would be free access to the bees. A false roof was suspended over the outer cover of the hive, which caught the rain and shed it beyond the hive walls. A light wooden framework over the two colonies was covered with canvas. In case of a light rain when the bees were still flying the canvas cover was not used, but during periods of hard dashing rains the canvas was dropped so low as to surround the hives completely and prevent any water from collecting on them.

Weighings were made hourly throughout the 24 hours of each day, including Sundays and holidays, three persons being assigned to the work on 8-hour shifts. One of the unfortunate circumstances connected with working on such a problem at Somerset, Md., is that the main honey flow is exceedingly short (seldom over 10 days to 2 weeks), thus increasing the probable error in all calculations by reducing the number of possible observations. The correlation coefficients for the spring honey flow are based on the one colony in 1922, and on the two colonies in 1923. For conclusions relative to the fall honey flow only the figures for the one colony of 1922 are available.

In order to calculate the relationship between changes of weight and weather conditions during the honey flow, only those days showing a net gain of 980 grams or over were used for the spring honey flow. The calculations for the fall period include all days from September 4 to October 5, irrespective of gains or losses; the two sets of data are therefore not strictly comparable.

Hourly thermograph and hygrograph records were made for use in calculating the mean temperatures and relative humidity; the mean of maximum and minimum temperatures was not used. Hartzell (16) has pointed out the chances of error in endeavoring to correlate

the average of maximum and minimum temperatures with various biological activities.

A rather rough record was kept of sunshine and cloudiness, but in all calculations the records of the United States Weather Bureau for Washington, D. C., were employed. There is a distance of 6 miles between the Weather Bureau Station in Washington and the Bee Culture Laboratory, at Somerset, Md., and it was found that only negligible differences existed between the recorded hours of sunshine for the two places. Records of solar radiation were also available through the kindness of Prof. H. H. Kimball, of the Weather Bureau, these being taken at American University, in Washington, about 1 mile from the Bee Culture Laboratory.

Calculations relating to the effect of wind upon honey production were not made. The anemometer maintained at the Bee Culture Laboratory was so located for another purpose that its records were not applicable to this problem.

The principal source of nectar available to the bees in this experiment was that from tuliptree (*Liriodendron tulipifera*). It is an excellent honey plant in this locality, yielding abundantly for about two weeks in early May. Since it blooms so early in the season, it is of the utmost importance that the beekeeper have his colonies strong, otherwise its nectar is wasted with the exception of what little is used for brood rearing. Occasionally black locust (*Robinia pseudacacia*) furnishes considerable nectar, but this plant is not dependable in this region. The period of the secretion of black locust coincides closely with that of tuliptree. In 1922 the bees worked on locust actively for several days, while scarcely a locust blossom was seen in 1923. A rainy May, especially rain for the first few weeks of May, spells crop failure for the beekeeper of this region. In this connection, attention should be called to the statement of Kenoyer (19) that a rainy May scarcely fails to precede a good honey season in the State of Iowa. This emphasizes the statement made earlier in this bulletin that with the present limited knowledge of the various honey plants a general application should not be made of data secured in a single locality with a certain species of plant. Kenoyer's work was based on data obtained in the clover region.

The coefficients of correlation between the various factors were calculated from the following usual formula for biometric calculations (7):

$$r = \left(\frac{\sum xy}{n} - \bar{x}\bar{y} \right) \frac{1}{\sigma_x \sigma_y}$$

Probable errors were calculated from the formula—

$$PE_r = \frac{.67449}{\sqrt{n}} (1 - r^2) = \chi_1 (1 - r^2)$$

The values of χ_1 were taken from Pearson (29), and the values of $1 - r^2$ from Miner's Tables (25)².

²All mathematical calculations are based on accepted biometric methods. The writer here records his thanks to Dr. Sewall Wright, of the Bureau of Animal Industry, for his unfailing assistance and advice in this phase of the work.

It may not be amiss at this place to give, for those not well versed in biometrics, a brief explanation of the terms "correlation" and "probable error." The following quotation is taken from Bowley (3, p. 316):

When two quantities are so related that the fluctuations in one are in sympathy with fluctuations in the other, so that an increase or decrease of one is found in connection with an increase or decrease (or inversely) of the other, and the greater the magnitude of the changes in the one, the greater the magnitude of changes in the other, the quantities are said to be *correlated*.

We may have either a positive or a negative correlation. When a change in one quantity or variable is accompanied by a direct change in the other the correlation is said to be positive. A perfect positive correlation has the value of 1. When the correlation is less than perfect it must be written as a decimal of one, such as .75. When the relationship between two quantities or variables is indirect, such as an increase in one being accompanied by a decrease in the other, the correlation is negative. A perfect negative correlation has the value of -1 . Such a relationship less than perfect must also be written as a decimal and is always preceded by a minus sign. Coefficients of correlation state in numerical terms the relationship between two variables. Graphs are useful in showing relationship between two variables, but they do not give numerical correlation values, and it is often difficult from the study of a graph to discover slight relationship or entire absence of relationship; this difficulty does not exist in the case of correlation. It is often convenient to think of a coefficient of correlation in terms of percentage; thus, a correlation written 0.8654 may be read as 86.54 per cent.

The probable error is a term applied in biometrics to make corrections in a calculation where complete data are lacking. Sample measurements must be made preliminary to a biometric calculation and it is rarely possible to obtain a complete series of samples. For instance, in calculating the correlation between temperature and the change in colony weight we may have the changes in weight occurring at 80°, 81°, 82°, and 84° F., the change at 83° F., being for some reason impossible to secure. The probable error gives the measure of unreliability due to lack of sufficient data. Obviously, the smaller the number of data involved the greater the probable error. The probable error is written with a combined plus (+) and minus (−) sign ($\pm$), and represents the true correlation as falling somewhere, either above or below the calculated correlation, by a difference most probably equal to the value of the probable error. A correlation written $.7500 \pm .0600$ indicates that there is an even chance that the true value lies between $.7500 + .0600$, or .8100, and $.7500 - .0600$, or .6900. To be significant, the coefficient of correlation should be at least about four times its probable error. When it is less than this the correlation approaches zero in its significance and is of importance primarily as showing whether a relationship is positive or negative. In discussing the probable error Yule (36, p. 311) says:

If an error or deviation in, say, a certain proportion p only just exceed the probable error, it is as likely as not to occur in simple sampling; if it exceed twice the probable error (in either direction), it is likely to occur as a deviation of simple sampling about 18 times in 100 trials—or the odds are about 4.6 to 1 against its occurring at any one trial. For a range of three times the probable error the odds are about 22 to 1, and for a range of four times the probable error

142 to 1. Until a deviation exceeds, then, 4 times the probable error, we cannot feel any *great* confidence that it is likely to be "significant."

To reduce the labor of calculating these data, in many cases the original data were coded so that all might be included in 10 classes; this was done so that the calculations could be made on sorting and tabulating machines. Because of this grouping many of the coefficients of correlation are smaller than they would have been had the original grouping been retained. In several cases calculations were made by both methods; the difference in results was in some cases as much as 5 per cent. In no case is this difference sufficient to invalidate the results, and, in fact, the results obtained from coding into 10 groups are somewhat safer, since they tend to give a smaller correlation.

Many of the coefficients of correlation shown in Tables 2 and 5 have no direct bearing upon the problem, and therefore are not discussed in this bulletin. They are given, however, to the end that partial correlations between any combination of factors may be calculated. It will be seen that high correlations may exist between variables having no direct relationship. In Table 2, for example, there is a coefficient of correlation of .5510 between the net gain and the average temperature of the night following. Obviously the temperature of the night can not affect the preceding day's gain; the correlation exists, nevertheless, owing to the combination of influences of the causative factors upon both the net gain and the temperature on the following night.

METHOD OF PRESENTING DATA

The graph in Figure 2 represents the manner in which the changes in colony weight during the 24 hours are classified to secure tangible and significant figures as a basis for all calculations. *A* is a fixed point which, on the vertical scale, represents the weight of the colony at 5 a. m. each day in the month of May. Loss of weight caused by departure of bees for the field begins at about this hour, sometimes earlier and sometimes later, but a weight taken at 5 o'clock constitutes a suitable average, since 4 o'clock is too early and 6 o'clock is too late for such a start. For the fall honey flow the whole graph is shifted one hour later, to adapt it to the shorter days, placing *A* at 6 o'clock. *B* is at the point denoting the lowest weight reached during the day and the hour at which this occurs. Although it may occur either in the morning or in the afternoon, the diminution in weight from *A* to *B* is called the *morning loss*, because this loss always precedes the day's gain in weight. This morning loss is due to the bees leaving the hive in flight. Morning loss may be graphically represented by a vertical line equal on the scale chosen to the diminution in weight, and will throughout this bulletin be designated by this name. *C* represents in both weight and time the point at which the colony regains its original morning weight. *D* represents in weight and time the turning point at which the colony has ceased to gain and begins to lose weight. The net gain for the day is therefore represented by a vertical line equal according to the scale to the difference in weight between the early morning reading (at *A*) and the weight reading at *D*. The latter point has not necessarily a fixed hour. The vertical distance between the weight coordinates of *D* and of *E* represents the

nocturnal loss due to evaporation and consumption for colony maintenance. *E* is, of course, located on the timescale 24 hours after *A*, and becomes the starting point (*A*) for the following day. The only two points which are fixed with regard to time are therefore *A* and *E*. In all diagrams except Figure 2 the base line is drawn, not from the point denoting the weight at the starting point (*A*), but from a zero point raised by an amount equal to the loss in weight between 4 and 5 (or, in the fall, 5 and 6) o' clock. This is done to show more clearly in the graphs the time when loss of weight of the hive actually begins, as the bees begin flying in the morning. Calculations of all data were, however, based on zero at the point *A* (actual weight at 5 or 6 o'clock). Nowhere in the calculations can allowance be made for consumption for colony maintenance, which remains an unknown factor. The gains during the day would be more, and the evaporation loss at night would be less, if this factor could be known.

The name "*midday decline*" is given to the decline in the amount of gain from hour to hour occurring near midday. Although gains

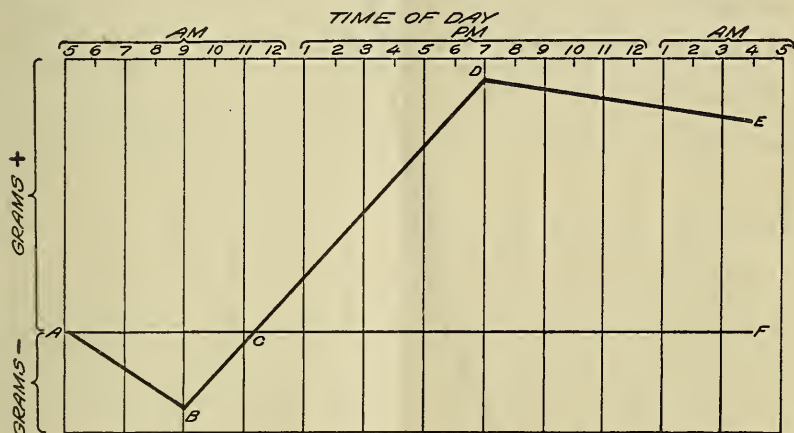


FIG. 2.—Division of changes in the weight of a colony of bees

are actually taking place during this period on most days, there is a noticeable difference in the rate of gain at this time as compared with that of the hours immediately before and after.

The 24 hours of the day are divided into diurnal and nocturnal periods, and the designations a. m. and p. m. are not used, since they have no biological significance. The differentiation of diurnal from nocturnal in this discussion is dependent upon the activity of the bees and not on light or darkness. The diurnal period ends and the nocturnal period commences when the weight of the colony ceases gaining, toward the close of the day, and the diurnal period begins, not necessarily at dawn, but at the hour when bee activity outside the hive becomes noticeable. Obviously, flight in the afternoons may be prevented or reduced by rain or inclement weather; and, to prevent the necessity of discarding data obtained on such days, the point *D* is located in the calculation of the data for 1922 at the time when bees cease gaining and begin to lose on the days immediately preceding and following the days in question,

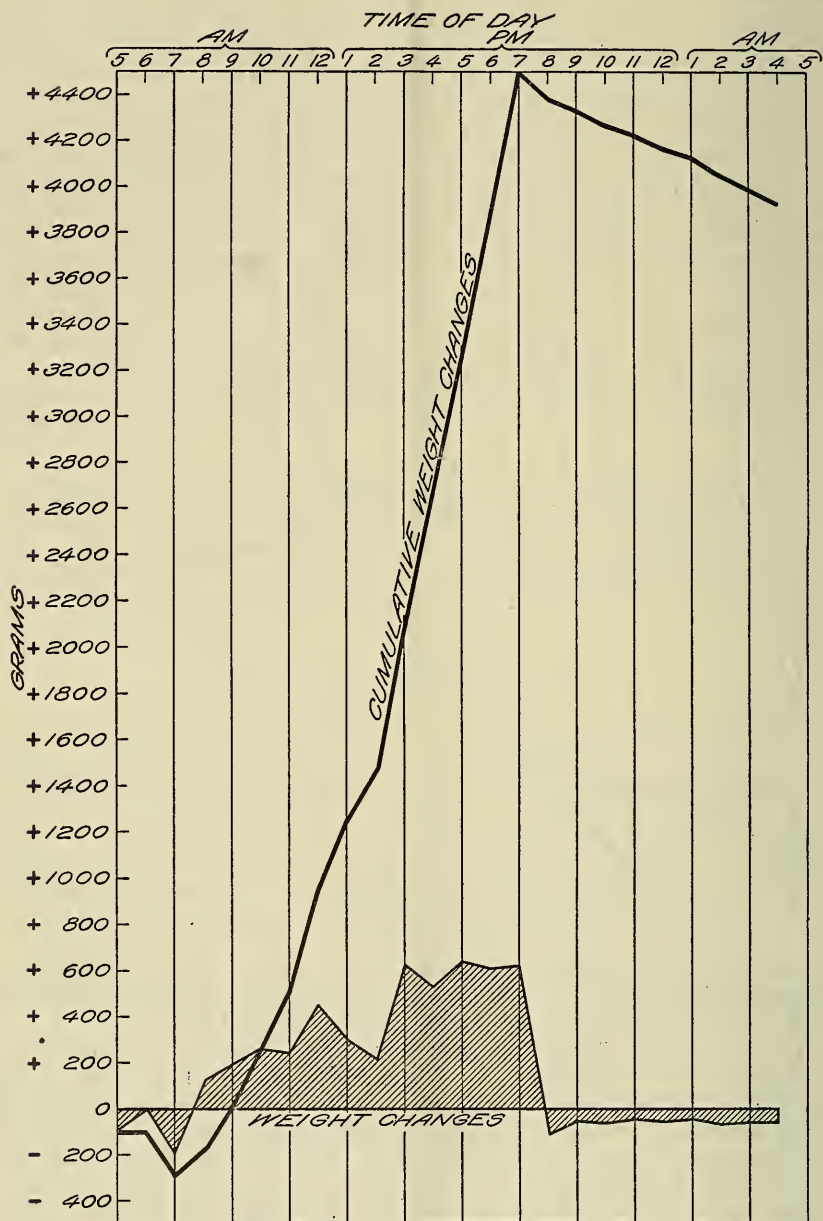


FIG. 3.—Graphs indicating changes of weight in colony AB, May 22, 1922. The solid line shows the cumulative weights; the shaded areas the variations in weight from hour to hour

thus making the diurnal and nocturnal periods of approximately equal length for all days studied for that year. This change was necessitated by the errors in weight due to water standing on the hives that year, as previously explained. In calculating the data for 1923 such a shifting of D was unnecessary, since the two hives used that year were under cover and no water stood on them. When rain interfered with flight during midday, and flight was later resumed, the point D takes its natural place at the close of flight activity for the day.

A graphic representation of changes in weight for a period of 24 hours is given in Figure 3. Either of two methods may be employed, both being shown in this graph. The heavy dark line represents cumulative gains and losses in weight, while the shaded portion shows differences in weight from hour to hour. In case of the shaded portion that part above the base line (shown as AF in fig. 2) is increase in weight and that below is decrease. It is readily seen that the shaded portion of the graph is more important than the line showing cumulative gain, since it magnifies small changes in the rate of gain or loss which might otherwise not be observed. For this reason the method showing differences in weight from hour to hour has been used in all graphs except those showing the net gain. In certain graphs both methods are used for greater clearness of differences. The effects of the various weather factors upon the hive-weight changes in the spring and fall are so different that these two periods must be considered separately.

COMPARISON OF CHANGES IN WEIGHT OF TWO COLONIES OF BEES

Beekeepers often assume great differences in the gathering ability of colonies of bees in the same apiary and under exactly similar external conditions. In the interpretation of the data obtained in this investigation it might be assumed that the colonies used were either unusually good or unusually poor at gathering nectar and pollen. In order to show that in the following calculations the individual characteristics of the colonies play a very minor rôle, it seems best at this point to insert a correlation of the changes in weight of the two colonies used in 1923. There is, in fact, little reason to believe that such differences in colonies as have been assumed by many beekeepers actually are important in considering the differences in honey crops obtained by various colonies in an apiary, and this is especially the case when observations are confined to a single race of bees, as was true in this experiment. When differences in the total acquisition of adjacent colonies of bees are noted, they must in most cases be attributed to differences in manipulation or care of the colonies, or to tendencies to retard gathering in certain cases because of crowding, or to a dominance of the swarming instinct, rather than to propensities for heavy or light gathering by the individual bees. Obviously, in the case of poor queens which are unable to keep up the population of their colonies there will be a reduction in the accumulation of stores

of the colonies headed by such queens, merely because of lack of sufficient bees; but this does not indicate any reduction in the propensities to gather of the individual bees. Merrill (24) reaches the same conclusion in his study of changes in colony weight. Whatever slight differences occur in the propensity of individual bees or colonies of bees to gather nectar and ripen honey are presumably due to actual anatomical differences rather than to marked differences in instinctive activities.

Table 1 gives the hourly changes in weight of colonies 1 and 2 for 13 consecutive days in 1923. The two colonies respond to external stimuli with remarkable similarity hour by hour. Every break in

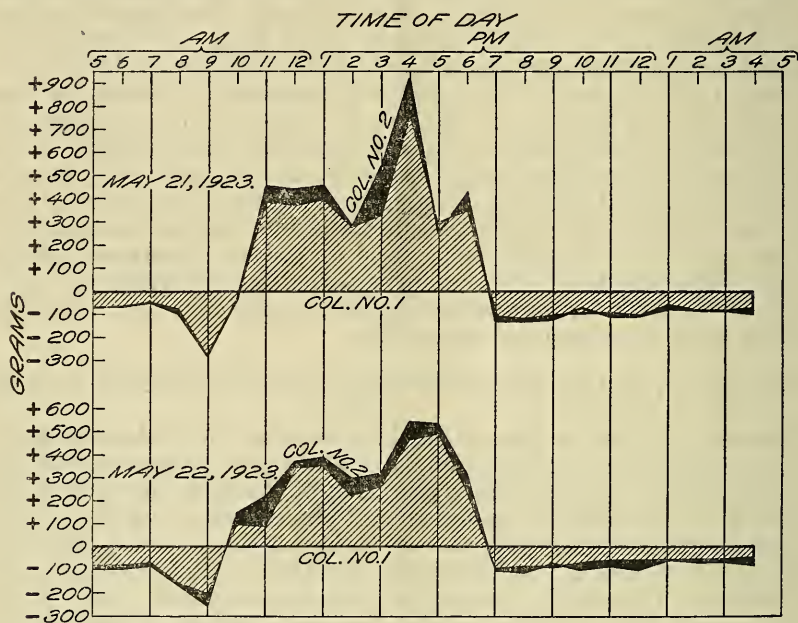


FIG. 4.—Hourly changes in weight of colonies 1 and 2, May 21 and 22, 1923. The shaded portion represents the gains and losses of colony 1 superimposed on those of colony 2. The black areas show the excess of the gain or loss of colony 2 over that of colony 1. (From Table 1.)

the weight graph of one colony is almost exactly duplicated in that of the other. Figure 4 represents graphically the weights of colony 1 superimposed on those of colony 2 for May 1 and May 22. The hourly differences in weight between the two are practically identical. So far as the amount of gain is concerned, colony 2 is the stronger, but the two behave almost the same from hour to hour. Figure 5 represents the average changes in weight hour by hour for the three colonies (one in 1922 and two in 1923) during the May honey flow. The similarity of these changes in weight of the three colonies is strikingly apparent, despite the fact that the data of colony AB were collected in May, 1922, and those of colonies 1 and 2 in May, 1923.

TABLE. 1.—Hourly changes in weight, in grams, colonies 1 and 2, May 18 to 30, 1923

Date	Colony number	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.	1 p. m.	2 p. m.	3 p. m.	4 p. m.
May 18	1	-20	-40	-150	140	250	270	290	230	50	330	150	400
Do	2	-40	-30	-180	-160	390	420	350	300	80	490	280	560
May 19	1	-60	-30	-80	-200	-130	80	320	280	170	210	370	350
Do	2	-40	-40	-110	-210	-190	140	330	330	130	340	480	420
May 20	1	-70	-60	-90	-180	0	250	280	430	310	220	310	760
Do	2	-80	-100	-100	-190	90	300	300	460	590	80	460	940
May 21	1	-70	-70	-50	-80	-280	-40	380	370	400	270	330	770
Do	2	-70	-70	-50	-90	-280	-30	460	440	460	270	530	920
May 22	1	-80	-80	-70	-160	-200	100	90	340	350	220	260	470
Do	2	-90	-90	-80	-170	-250	150	220	370	390	300	320	540
May 23	1	-50	-60	-70	-80	-220	230	-90	280	390	320	-60	-10
Do	2	-60	-70	-80	-80	-230	300	90	330	370	340	-80	-90
May 24	1	-30	-30	-50	-70	-110	140	300	330	0	460	430	450
Do	2	-40	-40	-60	-50	0	150	510	370	80	430	510	510
May 25	1	-60	-30	-60	-120	170	450	340	370	120	140	250	480
Do	2	-60	-50	-60	0	150	490	400	430	140	290	330	700
May 26	1	-50	-60	-80	50	170	330	530	290	120	30	240	500
Do	2	-60	-80	-50	140	190	330	450	380	60	190	450	660
May 27	1	-50	-50	-20	220	230	350	370	330	360	100	290	480
Do	2	-70	-70	50	340	200	340	410	370	240	30	420	560
May 28	1	-60	-50	-50	-60	20	130	270	300	520	100	170	580
Do	2	-60	-70	-70	-30	50	130	280	250	400	-40	250	660
May 29	1	-70	-50	-30	130	190	300	370	360	390	140	230	540
Do	2	-80	-80	10	210	150	210	240	370	300	50	120	650
May 30	1	-70	-70	-70	-80	-50	-60	40	30	200	180	130	230
Do	2	-60	-60	-80	-40	-330	150	30	140	190	180	100	190

Date	Colony number	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 p. m.	1 a. m.	2 a. m.	3 a. m.	4 a. m.
May 18	1	470	210	-70	-50	-80	-60	-50	-50	-60	-50	-50	-70
Do	2	660	360	-50	-50	-70	-70	-50	-50	-60	-50	-50	-70
May 19	1	360	590	130	-100	-100	-90	-80	-100	-60	-70	-40	-80
Do	2	470	710	280	-110	-100	-80	-80	-100	-60	-60	-40	-70
May 20	1	370	-130	-120	-70	-70	-60	-70	-90	-70	-60	-80	-70
Do	2	270	-130	-110	-90	-60	-80	-70	-70	-70	-70	-60	-80
May 21	1	290	350	-110	-120	-100	-90	-90	-110	-60	-80	-80	-70
Do	2	250	430	-130	-130	-120	-70	-110	-110	-70	-80	-80	-90
May 22	1	490	240	-90	-80	-80	-70	-60	-60	-60	-60	-60	-50
Do	2	530	310	-100	-110	-70	-90	-80	-100	-60	-70	-70	-80
May 23	1	140	90	-60	-20	-50	-30	-40	-20	-40	-20	-30	-30
Do	2	180	160	-50	-40	-70	-30	-60	-30	-40	-40	-40	-40
May 24	1	460	370	-30	-70	-60	-70	-50	-60	-40	-50	-40	-50
Do	2	550	560	-30	-110	-60	-100	-40	-80	-60	-80	-60	-60
May 25	1	400	400	70	-100	-90	-60	-70	-60	-50	-50	-50	-50
Do	2	580	560	-140	-130	-100	-80	-90	-90	-70	-70	-70	-80
May 26	1	400	480	360	-90	-70	-80	-50	-80	-50	-50	-50	-60
Do	2	550	640	440	-100	-90	-90	-80	-110	-60	-80	-80	-80
May 27	1	400	520	510	-100	-80	-90	-80	-80	-60	-60	-60	-60
Do	2	410	540	530	-90	-90	-100	-80	-120	-70	-60	-80	-70
May 28	1	560	750	490	-90	-100	-80	-70	-90	-60	-70	-70	-70
Do	2	610	760	450	-80	-100	-90	-60	-120	-70	-60	-80	-70
May 29	1	690	680	620	-80	-120	-80	-80	-110	-70	-70	-80	-80
Do	2	580	580	550	-80	-120	-60	-80	-110	-60	-60	-90	-80
May 30	1	520	710	150	-80	-80	-70	-50	-70	-50	-50	-50	-50
Do	2	440	620	140	-100	-50	-60	-50	-90	-30	-50	-60	-50

The coefficient of correlation of the changes in weight between colony 1 and colony 2 for the diurnal hours from 6 a. m. to 7 p. m., inclusive, based on 277 hours, is $.9076 \pm .0071$. The coefficient of correlation for the nocturnal hours, 8 p. m. to 5 a. m., inclusive, based on 190 hours, is $.8938 \pm .0098$. The correlations are high, and have an insignificant probable error, indicating that the activity in both

colonies was chiefly determined by factors other than internal ones. The differences observed between these two colonies were almost exclusively the actual differences of loss or gain, and the most probable explanation of these differences is to be found in the presumably smaller number of bees in colony 1. Actual counts of the bees of the two colonies could not be taken without vitiating the experiment. If any structural difference existed between the bees of the two colonies (as assumed by Merrill in his work), this was not determined, and with such high correlations as occur in the changes in weight of these two colonies such an explanation seems improbable. The high correlations do not indicate that any important internal difference, as in the condition of the queen, or the age of the bees, existed between the colonies. If there had been such differences so high a correlation would not have existed. It must be kept in mind that both colonies were amply supplied with storage and evaporating space.

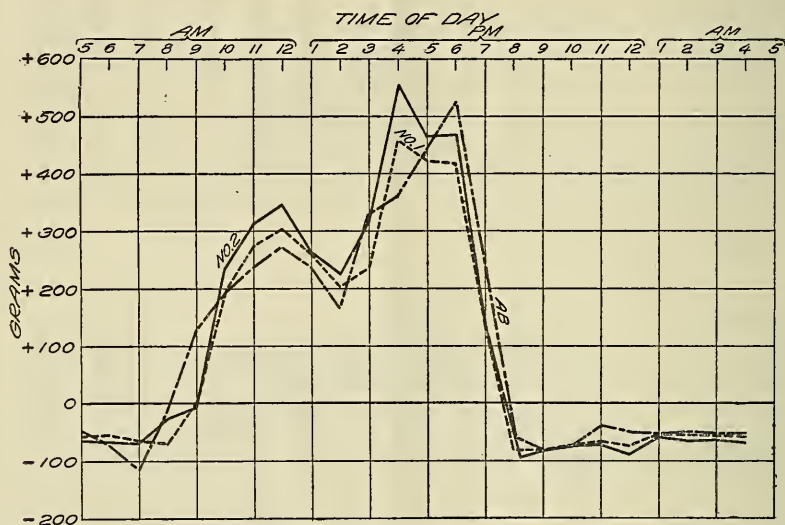


FIG. 5.—Graphs of the average variations, hour by hour, in the weight of Colonies 1, 2, and AB for the May honey flow. Note the minimum of the midday decline at 2 o'clock for the three colonies

If one of the colonies had been crowded for space, and this had interfered with the work of gathering, undoubtedly the coefficient of correlation would have been smaller.

An examination of these data indicates that the field forces of the two colonies were working at approximately maximum efficiency. The two colonies gathered a total crop for the year 1923 which compares favorably with that of any other colonies kept in the general locality. An examination of the striking similarity of the changes in weight of the two colonies at the time when both regained their morning weight and at the time of the midday decline of increase in weight strongly suggests that both colonies were gathering all the nectar which was available for them, in proportion to the number of bees available in each for field activity. This similarity is brought out much more clearly in the averages for the entire May honey flow (fig. 5) than in those for individual days (Table 1), since toward the

close of the honey flow colony 1 was apparently increasing in numbers more rapidly than colony 2. If it is assumed that both colonies were working at almost maximum efficiency, the midday decline in the rate of increase in weight to some extent agrees with Bonnier's statements (1) that less nectar is available early in the afternoon than earlier or later. Unless there exists some unknown influence on bee behavior at the time of the midday decline, it must be believed that the reduction in the rate of the increase in weight at this time is due to a reduction in the amount of nectar in the honey plants. Surrounding the Bee Culture Laboratory there is a vast acreage of tuliptrees, and there are comparatively few bees in the neighborhood other than those of the bureau apiary. Bonnier's assertion that bees carry partial loads of nectar when nectar is scarce is thus more probable, although the explanation may lie in the necessity for trips of longer duration at this time. There is no reason to believe that the bees actually gathered every drop of nectar available in the neighborhood at the time of this decline.

THE SPRING PERIOD

As has been stated, the data used in a consideration of the spring and fall honey-flow periods are not entirely comparable, since for the spring honey flow the only records used are those for days which show a net gain of at least 980 grams, whereas in the case of the fall honey flow the record for every day from September 4 to October 5 is used. Furthermore, the spring honey flow is much more intense in the vicinity of the laboratory than is that of the fall. For these reasons it seems best to consider the two periods separately. In the discussion immediately following, the various phases of the changes of weight during the day are taken up for the spring period, covering the time when the tuliptree was in bloom.

MORNING LOSS

Figure 3 illustrates the changes in weight during a typical day of the spring honey flow. In this case the morning loss is small and covers the time from 5 a. m. to 7 a. m., the majority of this loss occurring during the last hour. Usually the morning loss is quite small and rarely continues more than three or four hours. The amount and duration of the morning loss undoubtedly depend largely upon the proximity of nectar-producing plants and the abundance of their secretion, and upon weather factors prevailing at this time of the day. On some days the morning loss is negligible and scarcely distinguishable from the nocturnal loss, as on May 27 and 29, 1923 (fig. 6, b). The bees began to return to the hive almost immediately on these days, and thus with their increased weight more than compensated for the loss during the early morning hours. It is quite evident that on such days nectar was abundant and within easy reach of the bees.

The coefficient of correlation between morning loss and net gain is -0.6350 ± 0.0652 . This indicates that the smaller the morning loss the greater the resulting gain, and emphasizes the importance of locating an apiary as near as possible to the principal sources of nectar. The significance of morning loss will become more apparent later, in the consideration of the fall period.

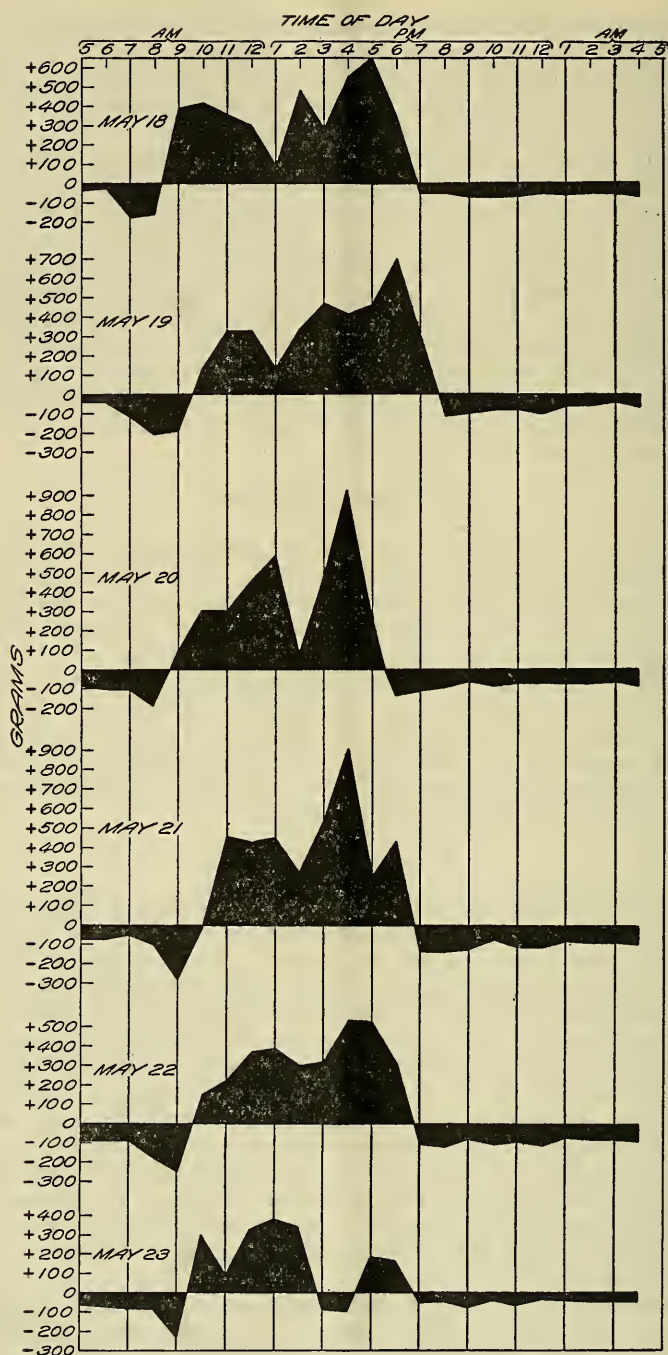


FIG. 6 (a).—Daily graphs for six consecutive days of colony 2, showing hourly changes in weight (see Table 1)

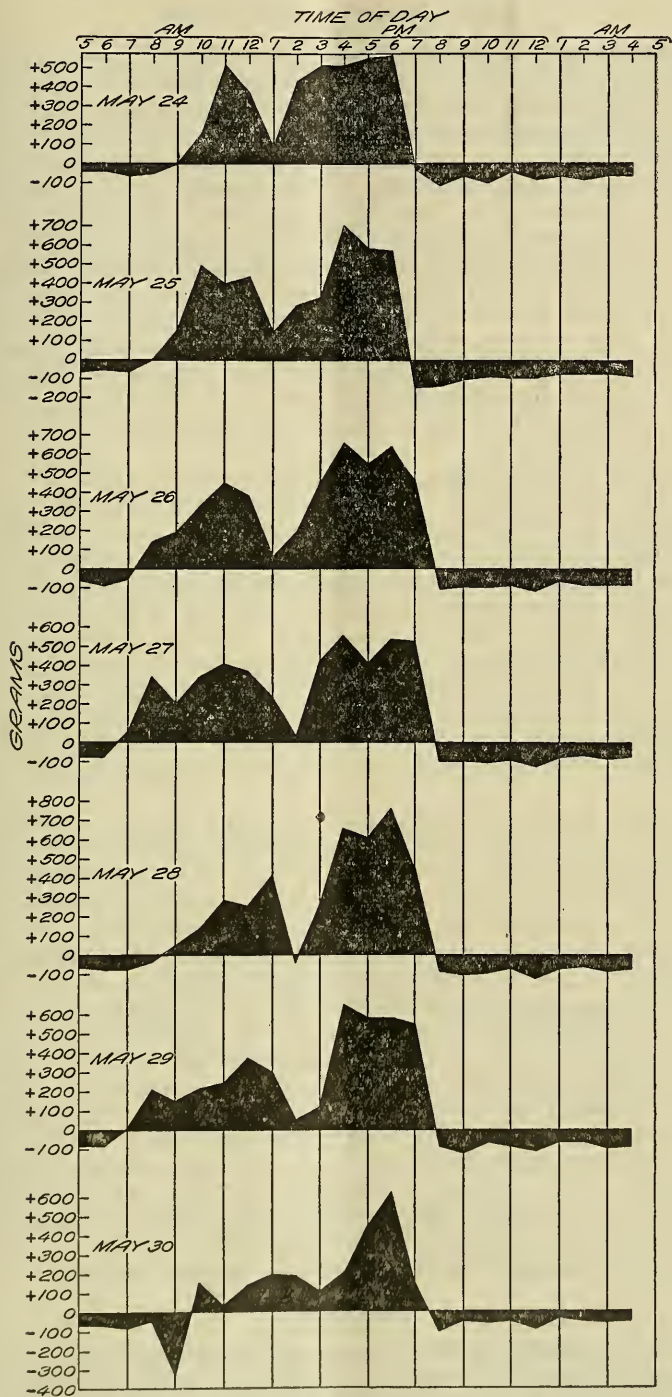


FIG. 6 (b).—Daily graphs for seven consecutive days of colony 2, following those of Figure 6 (a), showing hourly changes in weight (see Table 1)

MIDDAY DECLINE IN RATE OF GAIN

During the period of spring honey flow, after the morning loss in weight has ceased, which may occur at any time between 6.30 and 10 a. m. (the average hour for 1922 was 8 a. m., and for 1923 9 a. m.), the colony increases in weight with a more or less regular acceleration until midday. At this time a decided slackening usually occurs in the rapidity of gain in weight. This change in rate of gain is surprisingly constant in the time of its appearance and can be distinguished during practically the whole of the spring honey flow. The minimum rate of gain in weight, after gains have been established in the morning, usually comes at about 1 or 2 o'clock in the afternoon. On some days this decrease in rate of gain is decided, while on other days it is scarcely noticeable. When actual changes in weights are plotted this midday decrease in rapidity of gain can scarcely be seen, but when the data are plotted so as to show differences in weight from hour to hour it becomes quite obvious (figs. 3, 7, 8).

The cause of this change in rate of gain at midday is not entirely clear. Dufour (10) in his records mentions a similar phenomenon, and Bonnier (1, p. 163) connects a decrease in the amount of available nectar with low relative humidity and high temperatures prevailing at the same time of day. Bonnier measured the amount of nectar produced at various hours and found that less nectar is produced toward the middle of the day, when high temperatures and low relative humidities are usually encountered. He further found that at this time bees return to the hive with less than their maximum loads, and that fewer bees leave the hive for the field during this midday period, in comparison with periods before and after. Either of these two facts might be sufficient to account for the midday decline in rate of gain.

Figure 5, as stated, shows the average hourly changes in weight for colonies 1, 2, and AB for the spring honey flow. The similarity in the graphs for colonies 1 and 2 is not surprising, since these colonies were side by side and each was stimulated by exactly the same outside factors. The graph for colony AB, however, represents the changes for a colony one year earlier, but it closely follows the others. The midday decline in rate of gain is prominent in all three, and, although differing in magnitude, the three are intimately similar from hour to hour. The graphs for average temperature, relative humidity, and hours of sunshine bear no visible relation to the break in the three graphs showing gain and loss. The maximum temperatures for both years come later in the day than the midday decline, and the minimum relative humidity occurs at an hour slightly preceding. Until further investigations are made, Bonnier's (1, p. 164) observation of decreased nectar secretion on the part of the plant and the resulting effect on bee behavior must be accepted as the most logical explanation of this phenomenon, although the reasons which he gives for these changes on the part of the plants and the bees do not seem entirely satisfactory.

NET GAIN

The midday decline in rate of gain is included as part of the net gain, since an actual loss rarely occurs at this time during a good honey flow. The 13 graphs in Figure 6, for as many days, show

sharply how decidedly the midday decline reduces the amount of net gain. If the gaps caused by the midday decline were bridged the net gains would be appreciably larger. By theoretically bridging together the two peaks of the graphs of hourly gain, and thus eliminating the midday decline in rate of gain, the net gain for colony *AB* is increased 15.72 per cent. The net gains of colonies 1 and 2 are similarly increased 16.35 per cent and 16.95 per cent, respectively, so that in

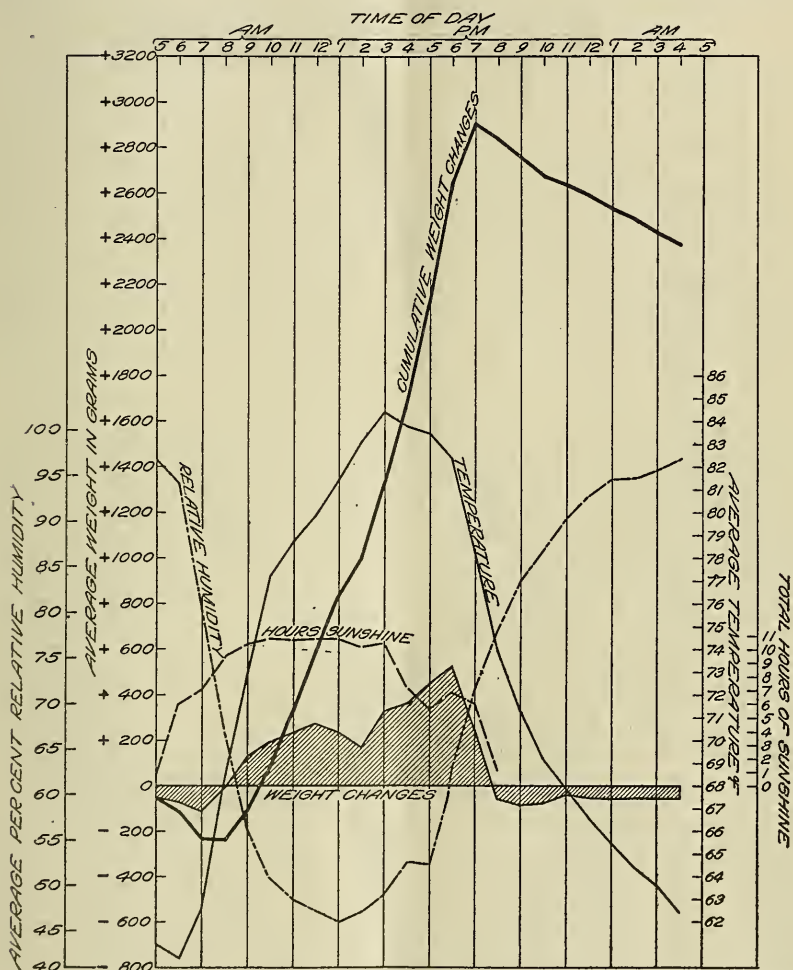


FIG. 7.—Graphs of average hourly weight changes, temperature, relative humidity, and total hours of sunshine. Colony *AB*, spring period

the years recorded the midday decline caused a loss of from 15 to 16 per cent in the net gain for the day.

Actual gains in weight do not occur immediately after the sun rises, but they do cease almost as soon as the sun goes down, as shown in Figures 7 and 8. Although bees make actual gains in hours recorded as cloudy, it is interesting to note that in 1922 the actual hours of sunshine during the spring honey flow totaled 124.4, while

increases in weight were recorded during 136.4 hours. In May, 1923, during the honey flow there were 138.5 hours of sunshine, while colony 2 made gains during 137.5 hours. The similarity between the hours of sunshine and hours in which gains were made are somewhat of a coincidence, for, as stated, gains are sometimes made in cloudy hours and gains are not made in all hours of sunshine. The effect of sunshine upon net gain will be discussed later (p. 36).

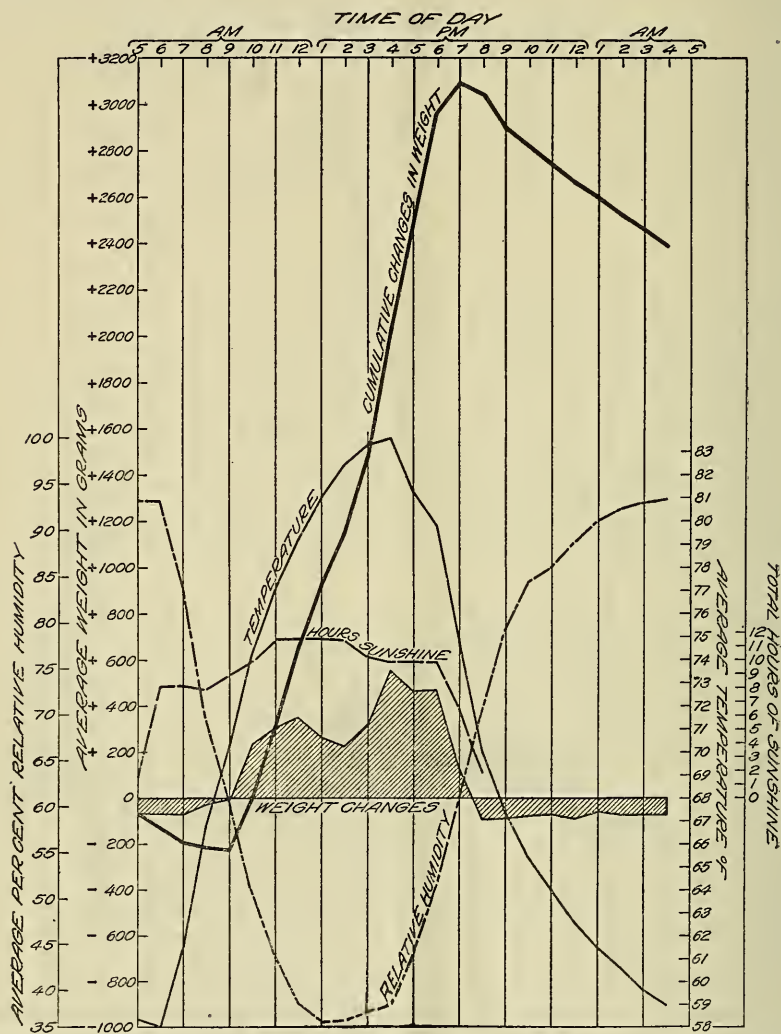


FIG. 8.—Graphs of average hourly weight changes, temperature, relative humidity, and total hours of sunshine. Colony 2, spring period

The temperature at the time when the colony ceases to gain in weight at the close of the day (figs. 7 and 8) is well above that at which bees are able to engage in effective outside work. This is shown by the fact that the average temperatures at the time of the morning loss, due to flights, are much lower than the temperatures

at the time that flights cease. The daily gains generally end abruptly, a fact suggesting that the bees do not desert the field at this time for lack of nectar.

NOCTURNAL LOSS

The nocturnal loss is calculated from the time that gain ceases until the bees leave for the field the following morning (fig. 2, D-E). Nocturnal loss is largely the result of the evaporation of water which is given off in the process of ripening honey. In this regard, nocturnal loss bears an intimate relation to the net gain.

The coefficient of correlation between nocturnal loss immediately following the day's gain and the net gain is $.4112 \pm .0909$. The correlation of the diurnal gain with the loss of the second night following is much less, being $.1890 \pm .1099$. In the second instance the coefficient of correlation is not twice its probable error, and so can not be considered as especially significant. This would indicate that the greater part of the necessary evaporation is accomplished during the first night and that little is left over until the following night. Evaporation naturally begins almost as soon as nectar is gathered, and therefore occurs during the day of gathering and probably during the following day, but in neither case is it possible to determine the amount of evaporation by day from a record of colony weights.

In 1923, colony 1, from May 18 to May 30, lost during the nights 25.29 per cent of the total amount gained. Colony 2 in the same period lost 24.69 per cent of the total gain. For 11 days in May, 1922, colony AB lost during the nights 17.85 per cent of the total gain. This lower percentage of loss in 1922 may have been occasioned by the character of the nectar collected, since considerable locust honey was available. It is also well known that the water content of nectar varies from year to year with different varieties of plants and with climatic factors. A calculation of Dufour's (11) data shows a loss of 26.16 per cent for 14 consecutive nights in May and June, when the minimum net gain was 970 grams, and the coefficient of correlation between net gain and nocturnal loss for this period is found to be $.6663 \pm .1002$. Maujean (23) found a nocturnal loss of 22.53 per cent of the net gain during the honey flow of 1905, and a loss of 27.40 per cent during that of 1904. A calculation of Maujean's data shows a coefficient of correlation of $.7868 \pm .0411$ between the net gain and the following night's loss, a correlation of $.5319 \pm .0795$ between the daily net gain and the loss of the second night following the day concerned, and of $.2813 \pm .1035$ between net gain and the loss of the third night following. These results would indicate that in this particular instance evaporation was practically complete by the end of the third night; a much slower evaporation than seems to have occurred in the present investigation. Hommell (18) states that according to Sylviac seven days is the minimum observed time required to change nectar completely to the consistency of honey; he thinks, however, that seven days is entirely too long for this minimum period, and points out that de Layens long ago discovered that in warm and dry weather nectar may be of such consistency as to permit almost immediate capping by the bees. Hommell points out that Huillon likewise gives a much shorter period for the completion of evaporation, and states that beekeepers can remove honey during the morn-

ing following a heavy honey flow without much danger that the honey will be too thin, since the greater part of the evaporation takes place during the first night.

The strength of the colony must likewise be an important factor in the rate of evaporation. While it is true that a weak colony collects less nectar than a strong one, it does not follow that the efficiency of the two colonies is proportional to their strength.

In studying the correlations in Table 2 it is seen that the external factors have but little influence on nocturnal loss. If there existed a strong internal individual influence in either one of these colonies, one would not expect such a high correlation between the nocturnal losses of colonies 1 and 2 (.8938, see p. 13). If external factors are important so far as nocturnal loss is concerned they must be other than temperature, temperature variation, relative humidity, or variation of relative humidity. Again the need for strong colonies is apparent. Weather conditions at night undoubtedly influence weak colonies to a greater extent than they do strong ones. Phillips and Demuth (30) in their wintering experiments have shown the detrimental effect of low temperatures upon weakened colonies, while strong colonies reacted normally to the same temperatures, if we take the survival of strong colonies and the death of weak ones as a criterion for differences in normal behavior.

THE FALL PERIOD

The data upon which the calculations for this period are based were secured from September 4 to October 5, 1922, during the period of the fall honey flow. No criterion for minimum gain was used in selecting the day to be correlated, and all days irrespective of gain or loss are included in the calculations. For this reason the figures can not be compared directly with those of the spring period, when only days having a minimum of 980 grams were selected. In studying the figures representing days of the fall period, it will be seen that the graphic presentations of hive weights are more significant than graphs showing the difference in weight from hour to hour. As in the analysis of the hourly weight changes of the spring period, weather factors, as they affect changes of weight in the fall, will be postponed for later discussion.

MORNING LOSS

The relation of morning loss to net gain appears to be the reverse of what it is during the spring period. The correlation between morning loss and net gain is $.5769 \pm .0825$, so that not only is the correlation between these two factors numerically greater than it is in the spring, but it is positive rather than negative. The morning losses generally were heavy, being from 390 to 1,690 grams. The morning loss is primarily brought about by the rapid exit of bees, as undoubtedly the returning bees with their loads of nectar more than make up for the loss due to the consumption of stores for maintenance of the colony, which constitutes a steady loss at all times. The duration of these losses varied from four to nine hours, and often equally as long a time would be required for the colony to regain its original weight of the early morning, this in turn leaving only



FIG. 9.—Hourly changes in weight of colony B; A, September 23, B, September 25, 1922

a few hours at the close of the day for the accumulation of net gain.

On September 25, 1922, colony B sustained the maximum morning loss of the season (fig. 9). The energy expended by the bees on this day, from the beekeeper's point of view, was misappropriated since the result of the day's labor netted the colony a loss of 255 grams. The weather of this day was ideal in every respect, and the bees evidently searched for nectar but found little or none. The average morning loss of the spring period is insignificant in comparison with that of the fall period. Figure 9 illustrates the magnitude of the morning losses on September 23 and 25, 1922, respectively, while Figure 10 shows the average loss for the entire fall honey flow of that year.

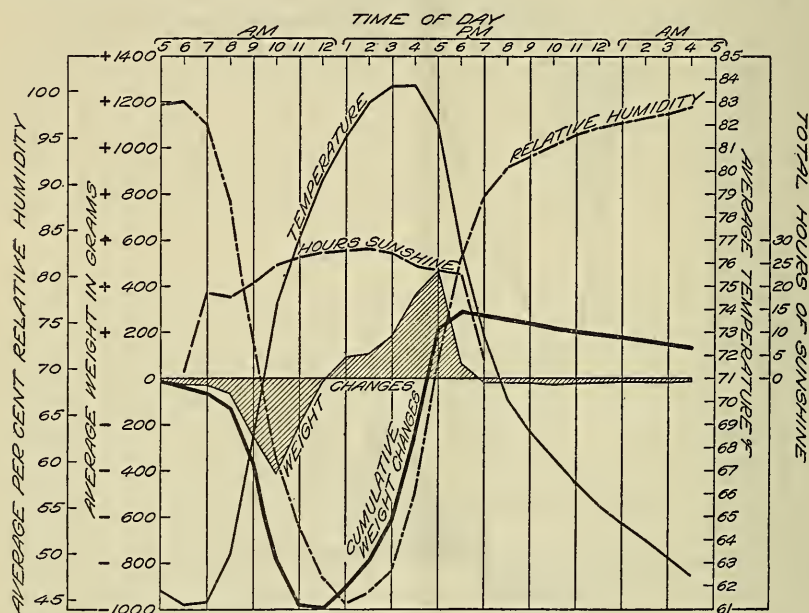


FIG 10.—Graphs of average hourly changes in weight, temperature, relative humidity, and total hours of sunshine. Colony B, fall period

MIDDAY DECLINE IN RATE OF GAIN

Although it is possible to distinguish the midday decline in rate of gain in weight during the majority of the fall days, it is seldom pronounced in its character. It is shown in the shaded portion of Figure 10, which presents the average variations in weight for each hour of the day in the fall period. The graphs of actual weights of fall days do not show this midday decline because it occurs so shortly after the time when the colony stops losing weight. The effect of the midday decline, as determined by bridging the gap at this period upon the net gain, is, however, greater than it is during the spring, since in this case the net gain was decreased 50.66 per cent on account of it.

NET GAIN

The net gain is accumulated late in the day. Figure 10 shows that the colony did not regain its original weight until between 4 and 5 o'clock in the afternoon, and since increase stops on the average at 6 o'clock any net gain must be accumulated between these hours. Undoubtedly the nature of the nectariferous plants abounding in any one locality will, together with the prevailing climatic factors, determine the time and amount of gain in weight. An entirely different picture may be expected in the buckwheat regions, since buckwheat is known to secrete nectar only in the forenoon.

Figure 1 well illustrates the vast differences, as shown by hourly changes in the hive weight, that may exist in the interrelationship of nectar-producing plants, bees, and weather factors. The two curves in this figure represent these changes for May 9 (solid line) and September 28 (dash line), 1922. On both of these days the net gain was practically identical, but the activities of the bees in securing this gain were vastly different on the two occasions. On the earlier day the morning loss ceased at 8 o'clock; on the other it continued until 11 o'clock and was more than seven times as great. On May 9 the original weight was regained by 12 o'clock, whereas on September 28 it was not regained until between 4 and 5 o'clock in the afternoon. The comparison of these two days also serves to emphasize the statement made earlier that to be of service weight records must be taken frequently and methodically. If only early morning and evening records are taken nothing can be known as to the time during the day when nectar is being brought into the hive, and, moreover, if the last weight of the day were made an hour or two earlier, one day might show a gain while the other shows a loss.

NOCTURNAL LOSS

The nocturnal loss during the fall is appreciably higher in comparison with the net gain than it is in the spring. For the days showing a net gain in Table 3, the nocturnal loss amounts to 48.72 per cent of the net gain. The correlation between these two is also much higher than it is in the spring, being $.8568 \pm .0333$. A calculation of Dufour's (11) data likewise shows a higher correlation between nocturnal loss and net gain for the fall, being $.8689 \pm .0458$, as opposed to a spring correlation of $.6663 \pm .1002$.

A higher correlation between net gain and nocturnal loss, as well as a larger per cent of loss, is naturally to be expected when net gains are small. Such a condition obtains in this case, since a larger part of the nocturnal loss is to be attributed to consumption for colony maintenance.

CORRELATIONS BETWEEN EXTERNAL FACTORS AND THE CHANGES IN COLONY WEIGHT

Having discussed the changes in weight of the colonies during the spring and fall honey flows and the correlations for the various parts of the day, it now is desirable to determine what degree of correlation exists between the changes in weight and the factors of the environment in so far as data are available for computation. These will be discussed in the following order: Temperature, relative humidity, solar radiation, and hours of sunshine. Numerous coefficients of correlation along these lines are presented in Table 2, together with their probable errors.

TABLE 2.—Coefficients of correlation between changes of colony weight in the spring and various weather factors

	Net gain	Nocturnal loss	Diurnal average temperature	Diurnal temperature variation	Diurnal average relative humidity	Diurnal relative humidity variation	Hours sunshine	Solar radiation	Nocturnal average temperature	Nocturnal temperature variation	Nocturnal average relative humidity	Nocturnal relative humidity variation
Net gain		0.4112 ±.0909	0.7529 ±.0473	0.5957 ±.0704	-0.3806 ±.0935	0.4229 ±.0898	0.6124 ±.0683	0.5525 ±.0760	0.5510 ±.0762	0.2941 ±.0959	-0.4495 ±.0873	0.0763 ±.1087
Nocturnal loss	0.4112 ±.0909		.3063 ±.0391	.0583 ±.1090	.0141 ±.1093	.1653 ±.1064	.3068 ±.0391	.2375 ±.1032	.1754 ±.1060	.3439 ±.0943	.1264 ±.1076	-.0654 ±.1089
Diurnal average temperature	.7529 ±.0473	.3063 ±.0391		.5717 ±.0736	-.1551 ±.1067	.3899 ±.0927	.5798 ±.0726	.4416 ±.0880	.7947 ±.0403	.2571 ±.1021	-.3382 ±.0929	-.0157 ±.1053
Diurnal variation of temperature	.5957 ±.0704	.0583 ±.1090	.5717 ±.0736		-.7272 ±.0515	.7852 ±.0419	.7703 ±.0444	.0727 ±.0599	.3185 ±.0983	.3419 ±.0966	-.5114 ±.0808	.5158 ±.0803
Diurnal average relative humidity	-.3806 ±.0935	.0141 ±.1093	-.1551 ±.1067	-.7272 ±.0515		-.7584 ±.0464	-.0420 ±.0643	-.6518 ±.0629	.1956 ±.1052	-.4264 ±.0895	.5883 ±.0721	-.7018 ±.0555
Diurnal variation of relative humidity	.4229 ±.0898	.1653 ±.1064	.3899 ±.0927	.7852 ±.0419	-.7584 ±.0464		.0780 ±.0591	.6280 ±.0662	-.0072 ±.1091	.1070 ±.1051	-.5314 ±.0781	.5294 ±.0553
Hours sunshine	.6124 ±.0683	.3068 ±.0391	.5798 ±.0726	.7703 ±.0444	.6420 ±.0643	.6780 ±.0591		.8826 ±.0241	.2059 ±.1047	.3822 ±.0934	-.6445 ±.0659	.6343 ±.0653
Solar radiation	.5525 ±.0760	.2375 ±.1032	.4416 ±.0880	.6727 ±.0399	.6518 ±.0629	.6280 ±.0662	.8826 ±.0241		.1012 ±.1082	.3358 ±.0970	-.5308 ±.0785	.6258 ±.0655
Nocturnal average temperature	.5510 ±.0762	.1754 ±.1060	.7947 ±.0403	.3185 ±.0983	.1956 ±.1052	-.0072 ±.1091	.2059 ±.1047	.3822 ±.0934		.3358 ±.0970	-.6445 ±.0659	.6343 ±.0653
Nocturnal variation of temperature	.2941 ±.0959	.3439 ±.0943	.2571 ±.1021	.3419 ±.0966	-.4264 ±.0895	.7947 ±.0403	.3822 ±.0934	.3358 ±.0970	.1012 ±.1082		-.5308 ±.0785	.6258 ±.0655
Nocturnal average relative humidity	-.4495 ±.0873	.1264 ±.1076	-.3382 ±.0929	-.5114 ±.0808	.5883 ±.0721	-.7584 ±.0464	.0780 ±.0591	.6280 ±.0662	-.0072 ±.1091	-.0739 ±.1083	-.0043 ±.1094	-.3373 ±.0969
Nocturnal variation of relative humidity	.0763 ±.1087	-.0654 ±.1089	-.0157 ±.1053	.5158 ±.0803	-.7018 ±.0555	.5294 ±.0553	.6343 ±.0653	.6258 ±.0655	-.6819 ±.0585			

TEMPERATURE AND CHANGES IN THE COLONY WEIGHT

In the vast literature of beekeeping few data are found to be useful in throwing light on the relation of external temperature to the changes in colony weight. Many experiments, however, have been conducted to ascertain the relation of temperature to nectar secretion. Of the latter, the work of Bonnier stands out most prominently. Unfortunately, he published but few of the actual data upon which his conclusions were based, so that it is difficult to make mathematical comparisons with the data herein presented or with the data of other investigators. Broadly speaking, the correlation between plant or animal activity and temperature is positive within, of course, certain limits. Most reactions, whether organic or inorganic in nature, are retarded by low temperatures, and increased by higher temperatures, although there are many examples to the contrary.

TEMPERATURE AND NET GAIN

During the spring period temperature has a marked effect upon net gain, the correlation between these factors being $.7529 \pm .0473$. This is a higher correlation than was found between net gain and any of the other weather factors, from which it appears that among those considered, temperature is the most important single factor influencing changes in the colony weight. Bonnier (*1*, p. 163), in referring to nectar secretion, states that the volume of nectar varies inversely as the temperature. Kenoyer (*20*) also says that the accumulation of sugar in the flower and its vicinity varies inversely as the temperature. In referring to honey production, however, Kenoyer (*19*) states that good honey months average slightly higher in temperature than poor ones, this being especially true of the fall and spring months, and that the yield is best on days having a maximum of 80° to 90° F. (26.7° to 32.2° C.). Ono (*26*, p. 15), in studying the secretion of extrafloral nectaries, does not lay much stress on temperature. He found that within the range of 15° to 25° C. (59° to 77° F.) the influence of temperature upon secretion is not remarkable; and that temperature seems to have merely an indirect influence in so far as it affects the plant itself. Harrault (*15*) states that for a given plant placed in suitable vegetative conditions the production of nectar increases with the increase in temperature and the quantity of sunlight, the production following general botanical laws. The writer's calculation of Harrault's rather scanty data gives a correlation of $.5258 \pm .0639$ between net gain and temperature. A negligible correlation of $.0065 \pm .1079$ was likewise calculated from data presented by Maujean (*23*).

Bonnier reached his conclusion by removing the nectar from various species of plants from hour to hour by means of a small pipette, and noting the temperature. The writer's calculations of Bonnier's data gave a correlation of $-.6581 \pm .0901$ between temperature and nectar secretion. Coefficients of correlations were also calculated from the same data between humidity and gain and between humidity and temperature, with the following results, where T =temperature, H =humidity, and N =volume of nectar:

$$r_{NT} = -.6581 \pm .0901$$

$$r_{NH} = .8040 \pm .0562$$

$$r_{TH} = -.9202 \pm .0243$$

Humidity is, of course, influenced by temperature. In order, therefore, to arrive at a more correct value of the effect of temperature upon nectar secretion, it is necessary to eliminate the effect of humidity by reducing this variable to a constant. This is conveniently done by the employment of the formula for partial correlation—

$${}_Hr_{NT} = \frac{r_{NT} - (r_{NH} \cdot r_{TH})}{\sqrt{(1 - r_{NH}^2)(1 - r_{TH}^2)}}$$

Substituting in this formula the above coefficients of correlation, and solving, we find that—

$${}_Hr_{NT} = .3306$$

It seems, therefore, according to Bonnier's data, that when humidity is constant nectar secretion varies directly with temperature.

The interpretation of similar data compiled by other investigators would be highly desirable at this place, so that results could be compared with those of Bonnier. The writer's calculation of Harrault's (15) data gives the following results:

$$r_{HG} = .2988 \pm .1228$$

$$r_{TG} = .5258 \pm .0639$$

$$r_{HT} = .2821 \pm .1241$$

In this case the net gain of a colony of bees was used, rather than the volume of nectar, and G therefore equals net gain. By substituting these values in Pearson's formula and solving we find that—

$${}_Hr_{TG} = .4826$$

The coefficient of correlation between net gain and temperature after correction is, therefore, somewhat lower than the direct correlation, but it is still positive.

In Table 2 the following coefficients of correlation are found:

$$r_{HG} = -.3806 \pm .0935$$

$$r_{TG} = .7529 \pm .0473$$

$$r_{HT} = -.1551 \pm .1067$$

In this case, by reducing the effect of humidity to a constant, we have—

$${}_Hr_{TG} = .7594$$

No attempt has been made in the present investigation to ascertain the optimum temperature for the maximum change in weight of a colony of bees. Kenoyer (20) found under experimental conditions that the optimum temperature for nectar secretion for most of the Leguminosae which he tested was 15° C. (59° F.). He also called attention to the fact that the phenomenon of the accumulation of stored sugar from starch at low temperature in the twigs of woody plants is well known, and, further, presented data which show that the same is applicable to floral tissues. He likewise ascertained that,

with an increase in temperature, the permeability of the protoplasts of the multicellular secreting hairs which cover the nectary of *Abutilon* rapidly increases. The osmotic pressures (intimately related to permeability in plants) of aqueous sucrose solutions were likewise found by Morse, as cited by Stiles (32), to vary directly with temperature, at temperatures generally encountered in working with plants. With the effect of low temperatures upon the accumulation of sugar on the one hand, and the effect of high temperatures upon permeability on the other, Kenoyer states that the evidence points to the conclusion that the secretion of nectar results from a balance between the two, and that the optimum temperature for secretion may be represented by the point where the negative graph representing temperature and sugar accumulation crosses the positive graph of permeability of protoplasts to sugar and temperature.

Phillips and Demuth (31), in referring to white clover (*Trifolium repens*), state that this species of Leguminosae may rarely be counted upon as a major honey source where the average summer temperature exceeds 75° F. (23.9° C.), and a more important consideration is that secretion is most rapid where there is a considerable daily range of temperature, the best results being observed when the night temperature is below 65° F. (18.3° C.), and the day temperature above that. The slight difference between Kenoyer's optimum temperature and the observations of Phillips and Demuth may be explained by the fact that the former was studying nectar secretion while the latter were referring to conditions as measured by the honey crop.

There are numerous records where low temperatures appear to have an important bearing upon nectar secretion. On the other hand, the literature of beekeeping contains many references, mainly observations by beekeepers, to the effect that high temperatures are necessary for an abundant secretion of nectar. Undoubtedly the physiological behavior of plants in nectar secretion varies somewhat with different species and under varying climatic conditions. Like Ono (26), Wilson (33) found that temperature makes but little difference in nectar production. In the case of branches of *Prunus laurocerasus*, however, he discovered that a temperature of at least 12° C. (53.6° F.) is necessary for the metamorphosis of the cell walls and the raising of the cuticle, and that after this activity of the nectary had passed a much lower temperature sufficed for continued secretion. Haupt (17) found that a certain minimum temperature was necessary to induce secretion and Demuth (9), in making observations to determine the temperature at which basswood (*Tilia americana*) begins to yield nectar, found that in northern Indiana this plant did not yield nectar until a temperature of 64° F. (17.8° C.) was reached.

From what has preceded, it is quite evident that considerable confusion exists regarding the true relation of temperature either to nectar secretion or to changes in colony weight. Much of this confusion is undoubtedly due to a lack of sufficient discrimination between the uses of the terms "nectar secretion" and "change in colony weight." So far as the changes in weight are concerned, the majority of the data indicate that during a honey flow the relation of these changes to temperature is positive. If there does exist a negative correlation between nectar secretion and temperature, it

appears evident that either the honey flora in the vicinity of Somerset, Md., does not respond during the spring period as did the plants studied by Bonnier and Kenoyer, or else that the temperature has such a pronounced effect upon the behavior of the bees that the effect upon nectar secretion is largely obscured. Hot, dry weather often occurs at periods when no nectar is being brought to the hive; at the hottest times, however, it is not at all uncommon for bees to gather large quantities of honeydew of insect origin. Since the bee is a cold-blooded animal it is but natural to expect increased activity with increasing external temperature.

Table 3 lists the coefficients of correlation between net gain and the various weather factors of the previous day. It will be seen that the coefficient of correlation between the net gain and the average temperature for the entire spring period is $.1783 \pm .1059$. This influence is positive but not otherwise especially significant, since the probable error is high. The correlation of net gain with average nocturnal temperature just preceding the gain is slightly higher, being $.2151 \pm .1043$. Evidently, according to the data presented, temperatures of the day on which gains are made have a more direct influence on colony gains than do those of the previous day or night.

TABLE 3.—*Coefficients of correlation between net gain in colony weight and various weather factors of the preceding day, with their mean and standard deviations for the spring period*

	Diurnal average temperature	Diurnal variation in temperature	Diurnal average relative humidity	Diurnal variation in relative humidity	Hours sunshine	Solar radiation	Nocturnal average temperature	Nocturnal variation in temperature	Nocturnal average relative humidity	Nocturnal variation in relative humidity
Net gain.....	0.1783 $\pm .1059$	0.3317 $\pm .0973$	0.0329 $\pm .1093$	0.0289 $\pm .1093$	0.0246 $\pm .1093$	-.0804 $\pm .1087$	0.2151 $\pm .1043$	0.2472 $\pm .1027$	0.0005 $\pm .1094$	0.0721 $\pm .1088$
Mean deviation.....	4.5261	4.9735	3.1578	4.6577	5.8682	6.4998	5.3682	4.6577	5.6840	4.1314
Standard deviation..	2.4895	2.3113	2.3230	2.4526	2.7067	2.4146	2.8603	1.8416	2.0148	2.3304

The data taken during the fall period give a correlation coefficient of $-.2310 \pm .1185$ between the average diurnal temperature and the change in weight. This figure is radically different from the correlation of .7529 existing between the average diurnal temperature and the net gain for the spring period. The probable error of the fall correlation is large, and this figure is therefore important chiefly because there is a negative correlation. This difference may be due in part to the fact that during the fall the activity of the colony in brood production is carried on under somewhat adverse conditions; that is, the effort necessary properly to care for the brood during the fall is proportionally greater than it is during the spring, and for this reason the bees will go to the fields under conditions otherwise not ideal. In such a case it may be that temperature has a more pronounced effect upon nectar secretion than upon bee behavior, and thus results in a negative correlation between average diurnal temperature and changes in colony weight. There seems little doubt but that a much greater effort is necessary on the part of the bees during the fall properly to carry on normal colony activity than is needed during the spring. Figure 1 illustrates a day in each of these two

periods when the net gains are approximately identical. For the spring day, the morning loss was small and ceased at 8 o'clock. From this time on the colony gained slowly but steadily until the close of day. Apparently only partial loads were carried during most of the day, and the bees made short trips to the field. Had either one of these two suppositions not been true, the morning loss would have been larger, or, if the bees had carried maximum loads and had made short trips, only a small portion of the field force would have been engaged in gathering. The fall day shows a tremendous morning loss with a regaining of the original weight late in the afternoon. Such a heavy loss, scattered over so many hours, would justify one in believing that the entire field force was active, and that the individual bees made long trips and perhaps carried but partial loads. Figure 9 (*B*) illustrates another day (September 25) of the fall period when the bees must have made tremendous efforts to secure what nectar was available. Table 4 presents various data relating to the fall honey flow of 1922.

TABLE 4.—*Changes in weight of colony B, and various weather data during the fall honey flow*

Date (1922)	Diurnal change in weight	Noc- turnal loss	Diurnal average tem- pera- ture	Diurnal tem- pera- ture varia- tion	Diurnal aver- age rel- ative hu- midity	Diurnal rela- tive hu- midity varia- tion	Sun- shine	Solar radia- tion	Noc- turnal aver- age tem- pera- ture	Noc- turnal tem- pera- ture varia- tion	Noc- turnal aver- age rel- ative hu- midity	Noc- turnal rela- tive hu- midity varia- tion	Morn- ing loss
	<i>Grams</i>	<i>Grams</i>	<i>°F.</i>	<i>°F.</i>			<i>Hours</i>		<i>°F.</i>	<i>°F.</i>			<i>Grams</i>
Sept. 4	-130	80	87.5	20	69.3	44	11.7	438.3	77.5	9	97.1	5	450
5	-70	60	85.3	18	68.6	53	9.6	432.6	73.2	12	97.7	8	420
6	-50	60	87.0	26	62.2	60	12.8	490.6	74.9	13	95.3	11	460
7	-10	50	87.6	24	64.5	56	8.7	450.1	78.0	12	96.0	9	390
9	-110	90	81.4	13	79.8	49	5.2	277.5	74.7	7	98.8	4	690
10	200	130	83.9	15	68.6	47	8.1	410.9	75.7	6	97.7	10	410
12	-20	20	75.1	9	71.6	54	6.3	301.4	61.0	14	97.5	10	820
13	290	120	74.6	27	54.5	64	12.5	495.2	64.9	9	96.1	9	800
14	550	200	81.9	27	58.0	64	12.5	478.9	74.0	11	95.5	14	850
15	550	170	84.7	21	66.3	55	11.1	464.4	74.8	9	97.5	6	920
17	50	90	69.6	19	56.0	55	7.9	308.0	55.7	11	95.6	8	1,010
18	90	170	69.0	22	53.3	36	10.4	413.6	61.9	5	90.8	9	1,080
19	370	190	70.5	18	63.3	51	5.7	271.9	61.1	13	97.7	13	1,170
20	350	190	66.9	18	76.1	45	6.4	289.1	62.5	8	98.1	8	1,185
21	690	290	70.7	15	68.6	48	3.7	311.9	61.5	13	97.0	11	1,310
22	410	235	69.6	22	68.5	57	3.2	323.2	60.5	14	98.3	6	1,510
23	1,395	390	77.4	33	58.2	72	10.4	397.3	65.8	17	96.9	10	1,430
24	960	510	78.3	32	66.5	62	6.0	329.8	68.4	23	71.5	49	1,620
25	-220	170	67.7	18	46.2	71	12.0	540.0	50.1	13	91.1	19	1,690
26	310	220	61.2	25	49.2	70	12.0	474.5	51.2	10	96.7	20	1,360
27	1,110	340	68.9	32	60.0	60	12.0	448.9	61.6	13	96.5	17	1,260
28	680	300	71.3	34	58.8	70	11.7	404.3	61.2	10	97.0	15	1,495
29	300	230	72.9	22	71.9	51	7.9	346.5	62.0	17	97.8	7	1,500
30	660	300	73.0	28	64.5	56	11.8	413.5	60.2	16	96.9	11	1,190
Oct. 1	440	230	74.4	30	61.0	64	11.8	431.5	58.8	6	97.1	11	1,190
2	380	220	75.2	34	63.4	66	11.6	396.8	60.1	16	98.5	7	1,150
3	350	215	76.6	34	62.0	64	11.7	361.1	65.5	13	97.7	8	1,070
4	215	210	78.0	27	63.9	60	10.8	306.6	69.5	12	95.5	9	1,005
5	240	225	83.0	32	53.5	74	11.6	365.5	69.6	14	87.0	23	900

It must be recalled that the data in the spring and fall periods are not entirely comparable, since days were not chosen in the fall with a minimum net gain of 980 grams. The difference between the correlations of temperature and net gain in the two periods is, however, so striking as to call for an explanation, and no definite explanation seems to be available. In determining the cause of this difference in correlation in the two periods it must be remembered

that there are striking differences in the conditions of the colony; in the spring the brood rearing is increasing and the population of the colony is not only greater but is made up predominantly of young bees; in the fall the population is smaller, brood rearing is decreasing, and many of the field bees are older than in spring. In the spring in the vicinity of the Bee Culture Laboratory the honey flow is heavy and nectar is abundant, whereas in the fall the daily gain is usually small and the plants yielding nectar do so in relatively small quantities. There may be an undetermined difference in the time of day at which nectar is secreted (as is found between clover and buckwheat, for example). In the spring, when nectar is unusually abundant, the gains may be largely attributable to the influence of increased temperature on bee activity, whereas in the fall the greater gains at lower temperatures may be associated with the inverse relationship which has been assumed between nectar secretion and temperature. Until more observations are made this must remain a matter of speculation.

It will be noticed in Table 2 that the correlation between diurnal variation of temperature and net gain in spring is $.5967 \pm .0704$. A wide daily variation in temperature on days of good gathering has long been noted by beekeepers. There is some evidence, as previously pointed out, that a preceding low temperature is necessary to induce nectar secretion, and that once started this secretion will continue at higher temperatures. The correlation of this same variable with the fall changes of weight (Table 5) gives approximately the same figure, namely, $.5570 \pm .0863$. The fact that diurnal variation of temperature affects the weight changes alike, both in the spring and fall, and the observation of this phenomenon by beekeepers, would indicate that this factor has a greater influence on nectar secretion than it does upon bee behavior.

For the fall period there is a correlation of $-.7586 \pm .0531$ between the average diurnal temperature and morning loss. The morning loss is largely brought about by flight activity, and is therefore really a quantitative measurement of it. Since there exists for this period a positive correlation between morning loss and change of colony weight, this fact would seem to indicate that the colder the weather the greater the gain, as in reality the correlation between the changes of colony weight and diurnal average temperature ($-.2310$) actually shows, though to a small degree. The correlation between diurnal variation of temperature and change of colony weight is positive, and the correlation between morning loss and diurnal variation of temperature is also positive, despite the fact that there is a large negative correlation between morning loss and the diurnal average temperature. In calculating this latter coefficient of correlation, the average temperature for the entire diurnal period was used, while the period of morning loss covers but half of this time. Since the maximum average temperature comes later than the end of the period of average morning loss, as shown in Figure 10, a correlation with the temperature for the hours actually coinciding with morning loss would undoubtedly result in a lower correlation between these two variables. The evidence in favor of the theory that during the fall temperature has a greater effect on nectar secretion than it has on bee behavior is thus not materially weakened.

TEMPERATURE AND MIDDAY DECLINE

As previously pointed out, the cause for the midday decline has been attributed to high temperature and low relative humidity, both prevailing at that time of the day. The minimum of the average midday decline occurs from 1 to 2 p. m. (figs. 7, 8, and 10). The maximum of the average temperature comes from 3 to 4 p. m. (figs. 8 and 10), although it occurred an hour earlier during the 1922 spring honey flow (fig. 7). Although the midday decline occurs during the hot part of the day, it does not coincide with the period of maximum temperature. Moreover, the coefficient of correlation between net gain and average temperature is high and positive for the spring period, so that it is difficult to give a satisfactory explanation of the occurrence of the midday decline on the basis of high temperature and low relative humidity. During the fall the relation between change of colony weight and the average diurnal temperature is negative and the coefficient is small. From the standpoint of the net gain, the midday decline during the fall is large, but from the standpoint of weight changes it is small and barely noticeable.

TEMPERATURE AND NOCTURNAL LOSS

The relation of temperature to nocturnal loss is surprising in view of the widespread importance usually attributed to it by beekeepers. One naturally expects to find a higher rate of evaporation on warm nights following days of good gain than on cool nights. This relation, however, is small, the coefficient of correlation between net gain and nocturnal average temperature being but $.1754 \pm .1060$.

Temperature variation seems to have a more important bearing, the coefficient of correlation between net gain and nocturnal variation of temperature being $-.3439 \pm .0964$. One interpretation for this would be that when there is a great variation in temperature during the night the bees are forced constantly to modify their temperature-regulating organization in such a manner that the temperature of the brood-chamber may be maintained constant. In doing this the task of evaporation is interrupted, resulting in a negative correlation. In other words, from the standpoint of evaporation, an even temperature is more desirable than a high temperature, within, of course, reasonable limits.

During the fall period the relation between temperature and nocturnal loss is the opposite of that existing in the spring period, the coefficient of correlation between the average nocturnal temperature and nocturnal loss being $-.3391 \pm .1108$. It would be contrary to physical laws to expect a higher rate of evaporation during cold nights than during warm nights. An explanation of this negative correlation seems to lie in the fact that the relation between changes of weight during the day and the respective nocturnal losses is high. This in turn would indicate that the incoming nectar was promptly cared for, and the existing outside temperature, instead of primarily affecting the rate of evaporation, has its effect principally upon the general activity of the colony, resulting in the consumption of larger quantities of stores on cold nights.

The coefficient of $.5136 \pm .0922$ between nocturnal loss during the fall and nocturnal variation of temperature can be explained in the same way. During the fall the amount of evaporation necessary is comparatively small because of the small amount of nectar gathered during this investigation, so that the various weather factors have little effect upon it, but have a considerable effect upon the work of the colony as a whole. The greater the range in temperature, the greater the consumption of stores, owing again, perhaps, to modification in the temperature-regulating arrangements of the colony. It is seen that variation of temperature has a greater influence upon the nocturnal loss, during both the spring and fall, than does the average nocturnal temperature. Variation of temperature at night produces noticeable disturbance.

RELATIVE HUMIDITY AND CHANGES IN COLONY WEIGHT

Even less is known regarding the influence of relative humidity upon changes in the weight of the colony than regarding the influence of temperature, probably largely because instruments for indicating relative humidity are not as widely distributed as are thermometers. Plant physiologists have, of course, studied the influence of relative humidity upon various phases of plant life, and to a limited extent upon nectar secretion. As in the case of temperature, there is no general agreement as to its relative value.

One of the difficulties encountered in determining the value of the influence of relative humidity upon any phase of plant or animal life is that relative humidity and temperature are intimately related. It is necessary, in a careful analysis of the influence of various weather factors upon physiological changes, to make due allowance for the influence of these variables upon each other. Wright (34), for instance, in recalculating the figures of Briggs and Shantz (4, 5) found that temperature and not wet-bulb depression was the more important variable influencing the daily transpiration of plants. Patterson (28) states that relative humidity as a factor influencing the growth of higher plants has been greatly overestimated. He found that elongation in etiolated shoots of the common bean, growing in pure silica sand, either 20 per cent or 60 per cent saturated with water, proceeded as rapidly in a relative humidity of 30 per cent as in a relative humidity of either 60 per cent or 90 per cent. When growing in silica sand, 5 per cent saturated, they grew less rapidly in a relative humidity of 30 per cent than in a relative humidity of 60 per cent or 90 per cent, but grew as rapidly in a relative humidity of 60 per cent as they did in one of 90 per cent.

All figures pertaining to relative humidity in the present bulletin were obtained from a self-recording hygrometer maintained in the laboratory apiary. This instrument tended regularly to record too high percentages of relative humidity, and consequently the figures in some of the tables appear to be above the average. This error in the instrument should not greatly affect the coefficients of correlation in which relative humidity figured as one of the variables, since the error appears to be fairly constant. No attempt has been made to determine the optimum or minimum relative humidity necessary for any activity of the apiary.

RELATIVE HUMIDITY AND NET GAIN

It has been shown that temperature influences nectar secretion and changes in the colony weight. Similarly, plants doubtless respond to changes in relative humidity according to the species and the location in which they grow. Some species of plants are known to secrete nectar under conditions of the greatest possible humidity; on the other hand, arid and semiarid countries contain many nectar-producing plants.

Hummell (18, p. 194) states that, other conditions being equal, the quantity of nectar increases with an increase in the relative humidity of the air. Ono (26), in discussing the influence of moisture on nectar secretion in extrafloral nectaries, says that "moisture is one of the conditions most favorable to the secretion of nectar, and its influence seems to be more or less direct. Dry atmosphere is in all cases unfavorable to the secretion." He cites a case in which cut twigs of *Prunus laurocerasus* were placed in a water bottle and held under a bell jar of moist air for three weeks. Despite the fact that these nectaries were washed daily (an operation which will often terminate secretion), they continued throughout the experiment to secrete nectar without decreasing either its quantity or the quantity of sugar contained in it. Wilson (33), working with the same species of plant, found that after a branch of *Prunus laurocerasus* had been made to secrete nectar by being placed under a moist bell jar, it continued to do so without water and in the dry air of an ordinary room, until the whole branch had lost more than one-fourth of its weight by withering. Kenoyer (20) discovered that by increasing the relative humidity the production of water was increased, but not that of sugar from nectaries.

Bonnier (1) found that the secretion of nectar varies directly with relative humidity. Although he realized (2) the complex rôle which relative humidity plays in plant physiology, he made no corrections for the effect of other variables upon relative humidity in his studies on nectar secretion. In calling attention to the midday decline, and accounting for it by the low relative humidity and the high temperature prevailing at that time, he made no effort to assign more importance to one than to the other. The writer, in calculating Bonnier's data, found the coefficients of correlation, as stated under the discussion of temperature. In order to arrive at a corrected value for the effect of relative humidity by reducing temperature to a constant, we substitute in the following formula the numerical values of the proper coefficients (see p. 27 for correlation values), and obtain—

$$r_{NH} = \frac{r_{NH} - (r_{NT} \cdot r_{TH})}{\sqrt{(1 - r_{NT}^2)(1 - r_{TH}^2)}} = .6605$$

Thus the effect of temperature reduces the coefficient of .8040 between relative humidity and nectar secretion to .6605.

The substitution in the above formula of the coefficients calculated from Harrault's (15) data gives—

$$r_{NH} = .1844, \text{ where } r_{TH} \text{ is } .2988$$

The writer found a correlation coefficient of $-.3806 \pm .0935$ between change in the colony weight and diurnal relative humidity for the spring period. In making a temperature correlation by means of the same formula, he found $r_{\text{temp}} = -.4058$. In this particular instance, it appears that dry atmosphere has a beneficial effect upon the change in colony weight.

The fall period showed less, or practically no, correlation between changes of colony weight and diurnal average relative humidity, the correlation being $-.0960 \pm .1240$.

It is interesting to note from Tables 2 and 5 that a wide variation of diurnal relative humidity has a beneficial effect upon change of colony weight, and that the coefficients of correlation in this case are higher than those with the diurnal average relative humidity.

The condition of the diurnal or nocturnal relative humidity of the day preceding has practically no effect upon change of colony weight.

RELATIVE HUMIDITY AND MIDDAY DECLINE

Figures 7, 8, and 10 show that the average minimum relative humidity is reached previous to the average low point of the midday decline. This fact, together with the existence of a negative correlation between net gain and diurnal relative humidity, makes it difficult to assign low relative humidity as the cause for the midday decline.

RELATIVE HUMIDITY AND NOCTURNAL LOSS

During the spring period the nocturnal relative humidity plays a small part in the nocturnal loss. The coefficients for both the average and the variation in relative humidity are small and have large probable errors.

For the fall figures these factors are more important. The coefficient of $-.4821 \pm .0961$ for the average nocturnal relative humidity with nocturnal loss signifies that the drier it is at night the more the colony loses in weight. The greater the variation in relative humidity during a night, the greater the loss, as is shown by the coefficient of correlation of $.5391 \pm .0888$. Thus it is seen that variation in relative humidity plays a more important part than the average relative humidity upon nocturnal changes in colony weight.

SOLAR RADIATION AND SUNSHINE

It is a well known fact that both solar radiation and sunshine exert a profound influence upon animal and plant life; it is therefore not surprising to find that these two factors play an important rôle in changes of colony weight. A number of investigators have attempted to learn the effect of light upon nectar secretion, but, as in other experiments upon nectar secretion, various species of plants have been used with the result that authorities differ in their conclusions.

Ono (26) placed *Ligustrum lucidum*, *Viburnum japonicum*, *V. opulus*, *Prunus yedoensis*, and *P. laurocerasus* in a dark moist chamber and found that their young extrafloral nectaries produced no nectar at all, but that their fully developed nectaries secreted in the dark equally as well as in the sunlight. In the case of *P. laurocerasus* this plant continued to secrete nectar in ample quantities for three weeks while placed in a dark chamber, the nectaries being washed daily.

He concludes that the influence of light on the secretions of the nectaries is of an indirect nature, except in the case of *Vicia* and some species of *Euphorbia*, these exceptions being noted by Haupt (17). As a matter of fact, Ono concludes that all external factors are of slight value in comparison with the inner conditions of the nectaries. Secretion, he thinks, may occur by mere chance; and the factors which are favorable to the life and growth of the plant at the same time promote the secretion of nectar.

Haupt (17) found that for certain plants, e. g., *Euphorbia* and *Vicia*, the secretion of nectar is profoundly influenced by light, especially by the red and yellow rays of the sun's spectrum. The secretion of nectar occurs only in light, and in darkness or in blue light nectaries already containing sugar resorb this substance.

Gardiner (12), in commenting on the discoveries of Wilson (33) regarding nectar secretion, says, "I am led to think that this goes far to explain both his own and Darwin's (6, p. 403) observations, that the exudation of nectar takes place more rapidly in sunlight, for according to my own observations as regards waterglads and the like it does not seem probable that the power of secretion as such is accelerated by light." However, Wilson (33) does not lay much stress on the effect of light upon secretion, as Gardiner would have one believe, for in Wilson's conclusions he states that many plants secrete as well in the light as in darkness, while others require either direct sunlight or strong diffused light for secretion. Harrault (14) observed that some plants can yield certain quantities of nectar under weak solar rays but that most plants do not yield nectar even in slight shade. In discussing the influence of external factors on plant transpiration, Livingston, in his revision of Palladin's work (27, p. 133), says that light is undoubtedly the most important.

In the present investigation the total hours of sunshine seem to have a somewhat greater effect upon net gain during the spring period than does solar radiation. The coefficient of correlation of the former with net gain is $.6124 \pm .0683$, while for the latter with net gain it is $.5525 \pm .0760$. In the attainment of the flowering stage of plants, Garner and Allard (13) found that length of day is much more important than the total amount of solar radiation received by the plant. This discovery is interesting in view of the fact that the secretion of nectar accompanies the attainment of the flowering stage for practically all of the important nectar-producing plants.

These writers state that—

Except under such extreme ranges as would be totally destructive or at least highly injurious to the general well-being of the plant, the result of differences in temperature, water supply, and light intensity, so far as concerns the sexual reproduction, appears to be, at most, merely an accelerating or retarding effect, as the case may be, while the seasonal length of day may induce definite expression, initiating the reproductive processes or inhibiting them, depending on whether this length of day happens to be favorable or unfavorable to the particular species.

Further investigation along these lines may result in throwing more light on the effect of weather factors on bee behavior, and on plant behavior in so far as the secretion of nectar is concerned. A correlation of length of day with nectar secretion of various plants may likewise help to clear up the many differences in plant behavior which beekeepers attribute to differences of locality.

For the fall period the coefficients of correlation for both solar radiation and hours of sunshine with changes of colony weight are practically zero, while negative correlations, having large probable errors, exist between these variables and morning loss.

THE EFFECT OF UNKNOWN FACTORS ON CHANGES IN COLONY WEIGHT

In this investigation, correlations have been made between changes in colony weight and 10 different factors in the accompanying weather conditions, some of these also being used in correlations with the conditions for the day or night previous to the change in weight. There are so many external and internal factors which may influence the physiological processes of nectar-secreting plants and the behavior of bees in gathering and ripening nectar that it is not probable that the factors for which data were obtained are the only ones which may influence the changes in colony weight.

For the purpose of ascertaining to what degree the influences have been determined and to what degree unknown factors are involved, an attempt has been made mathematically to find the values of all unknown factors. Such a determination throws no light on the actual character of these unknown factors, on the degree of their influence individually, or whether some are positive and some negative, but merely gives the mass value of all factors so far undetermined.

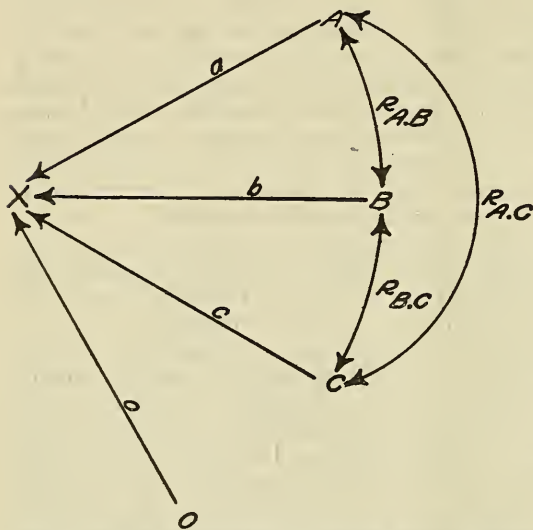


FIG. 11.—Graphical representation of quantities and their relations involved in the determination of coefficients of correlation

The method used in this work is based on Pearson's theory of multiple correlation. The square of the coefficient of multiple correlation between one variable and a number of others measures the extent to which the given variable is determined by the others, while 1 minus this square measures the degree of determination by independent residual factors. In a system of variables X , A , B and C , in which nothing is assumed of the causal relationships between them, X , which in this case is change in colony weight, is determined by the variables A , B , and C (weather factors) and by all other residual actors. This method has been described in detail by Wright (35).

In Figure 11, taken from Wright, the small letters represent the path coefficients, and the capital letters the variables, used in determining the coefficients of correlation. The path coefficients are not equal in value to the coefficients of correlation determined by direct correlation methods, but may be defined as the ratio of the standard

deviation of X due to each variable to the total deviation of X . O represents all residual or unknown factors. From such data we have several simultaneous equations; as many in number as there are variables considered.

The following simultaneous equations are obtained:

$$r_{XA} = a + br_{AB} + cr_{AC}$$

$$r_{XB} = ar_{AB} + b + cr_{BC}$$

$$r_{XC} = ar_{AC} + br_{BC} + c$$

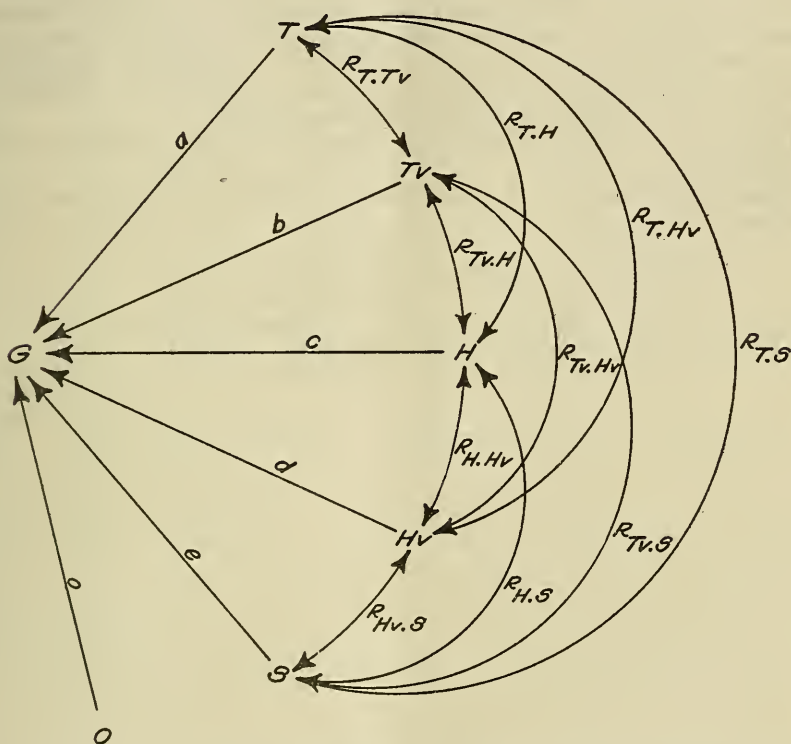


FIG. 12.—Graphical representation of quantities and their relations involved in the correlation of factors of increase of weight of the colony during the spring and fall honey flows

By solving these simultaneous equations the values of the path coefficients a , b , and c are derived. The total extent to which X is determined by the variables A , B , and C is obtained from the following formula (Wright):

$$1 - o^2 = ar_{AX} + br_{BX} + cr_{CX}$$

Applying this method to the correlations and other data obtained relating to changes in weight of the colonies during the spring honey flow (Table 2) and those for the fall honey flow (Table 5), calcu-

lations have been made by including five of the weather factors. In Figure 12 the symbols are as follows: G =net gain (changes of colony weight in the fall period), T =average temperature, Tv =temperature variation, H =average relative humidity, Hv =variation of relative humidity, S =hours of sunshine, L =nocturnal loss, and o =residual, unknown factors. It will be noted that only 5 of the weather factors are here included, although 10 were determined in the original data, but to have included all 10 would have made too unwieldy a calculation. In order to make comparison between the spring and fall periods the same variables were used in both cases. Hours of sunshine were used instead of solar radiation because this factor has a larger coefficient of correlation with net gain and because there is a high correlation between these two factors of themselves. None of the nocturnal factors were included in this calculation, as being of probably little value in their influence on net gain.

For these five weather factors is obtained the diagram shown in Figure 12.

From this diagram the following simultaneous equations are evolved:

$$\begin{aligned}
 r_{GT} &= a & + br_{TTv} & + cr_{HT} & + dr_{HvT} & + er_{ST} \\
 r_{GTv} &= ar_{TTv} & + b & + cr_{HTv} & + dr_{HvTv} & + er_{STv} \\
 r_{GH} &= ar_{TH} & + br_{TvH} & + c & + dr_{HvH} & + er_{SH} \\
 r_{GHv} &= ar_{THv} & + br_{TvHv} & + cr_{HHv} & + d & + er_{SHv} \\
 r_{GS} &= ar_{TS} & + br_{TvS} & + cr_{HS} & + dr_{HvS} & + e
 \end{aligned}$$

TABLE 5.—Coefficients of correlation between changes of colony weight in the fall and various weather factors, with their mean and standard deviations

	Change in weight	Nocturnal loss	Diurnal average temperature	Diurnal variation of temperature	Diurnal average relative humidity	Diurnal variation of relative humidity	Hours of sunshine	Solar radiation	Morning loss	Nocturnal average temperature	Nocturnal variation of temperature	Nocturnal average relative humidity	Nocturnal variation of relative humidity
Change in weight													
Nocturnal loss	.8568 ±.0333												
Diurnal average temperature	-.2310 ±.1185	-.3845 ±.1067											
Diurnal variation of temperature	.5570 ±.0863	.5565 ±.0864	.0538 ±.1248										
Diurnal average relative humidity	-.0960 ±.1240	-.1867 ±.1208	.2847 ±.1150	.0538 ±.1248									
Diurnal variation of relative humidity	.3300 ±.1071	.3886 ±.1063	.6974 ±.0643	.6974 ±.0643									
Hours of sunshine	.0395 ±.1248	.0039 ±.1252	.5746 ±.1211	.5746 ±.1211									
Solar radiation	-.0341 ±.1251	-.1175 ±.1255	.2631 ±.1182	.2631 ±.1182									
Morning loss	.5769 ±.0635	.7888 ±.0473	.7586 ±.0531	.7586 ±.0531									
Nocturnal average temperature	-.1661 ±.1217	-.3391 ±.1108	.9054 ±.0225	.9054 ±.0225									
Nocturnal variation of temperature	.4455 ±.1003	.5136 ±.0922	.0203 ±.1251	.0203 ±.1251									
Nocturnal average relative humidity	-.2022 ±.1201	-.4821 ±.0951	.0564 ±.1248	.0564 ±.1248									
Nocturnal variation of relative humidity	.3177 ±.1126	.5391 ±.0888	-.0730 ±.1245	-.0730 ±.1245									
Mean deviation	2.9654	3.1723	5.2757	5.0343	4.4481	4.9309	6.0688	4.0000	4.5171	4.9654	3.2413	7.6205	1.4137
Standard deviation	2.2817	2.1021	2.5313	2.4705	2.1270	2.4627	2.8155	2.6321	2.7118	2.4564	1.9415	1.6700	1.7324

From values found in Table 2 are derived the following values of the correlations specified, used in calculating the value of the unknown factors influencing change of colony weight during the spring period:

DIURNAL

$r_{G.T} = .7529$	$r_{T.Tv} = .5717$	$r_{Tv.Hv} = .7855$
$r_{G.Tv} = .5967$	$r_{T.H} = -.1551$	$r_{Tv.s} = .7327$
$r_{G.H} = -.3806$	$r_{T.Hv} = .3899$	$r_{H.Hv} = -.7584$
$r_{G.Hv} = .4229$	$r_{T.s} = .5798$	$r_{H.s} = -.6420$
$r_{G.s} = .6124$	$r_{Tv.H} = -.7113$	$r_{Hv.s} = .6780$

NOCTURNAL

$r_{L.T} = .1754$	$r_{T.Tv} = -.0739$	$r_{Tv.H} = -.5655$
$r_{L.Tv} = -.3439$	$r_{T.H} = -.0043$	$r_{Tv.Hv} = .4493$
$r_{L.H} = -.1264$	$r_{T.Hv} = -.3373$	$r_{H.Hv} = -.6819$
$r_{L.Hv} = -.0654$		

Solving, we find the values of the path coefficients to be—

$$a = .6898, b = .0630, c = -.3217, d = -.2075, e = .1004$$

By knowing the values of the path coefficients, the value of o^2 can be determined from the following formula:

$$p_{GT}r_{GT} + p_{GTV}r_{GTV} + p_{GH}r_{GH} + p_{GHV}r_{GHV} + p_{GS}r_{GS} = 1 - o^2$$

and is found to be—

$$o^2 = .34705$$

the degree of determination of unknown factors for the spring period.

In determining the value of the unknown factors influencing nocturnal loss during the spring, only four variables were used, namely, nocturnal average temperature, temperature variation, nocturnal average relative humidity, and variation of relative humidity.

The values of the path coefficients were obtained by solving the following simultaneous equations:

$$\begin{aligned} r_{LT} &= a + br_{Tvt} + cr_{HT} + dr_{Hvt} \\ r_{LTV} &= ar_{TTv} + b + cr_{HTv} + dr_{Hvtv} \\ r_{LH} &= ar_{TH} + br_{Tvh} + c + dr_{Hvh} \\ r_{LHV} &= ar_{THv} + br_{Tvhv} + cr_{HHv} + d \end{aligned}$$

and are—

$$a = .07329 \quad b = -.58681 \quad c = -.57172 \quad d = -.16688$$

The values of the unknown factors are determined by substituting the known values and solving the equation—

$$p_{LT}r_{LT} + p_{LTV}r_{LTV} + p_{LH}r_{LH} + p_{LHV}r_{LHV} = 1 - o^2$$

whence—

$$o^2 = .70268$$

It is quite evident in comparing the values of the unknown factors for the diurnal and nocturnal periods that so far as nocturnal loss is concerned the weather factors used have but little influence. The causes influencing the nocturnal loss during the spring period evidently lie chiefly within the colony itself.

The variables used in calculating the values of the unknown factors during the spring period were also employed in determining the values of the unknown factors for the fall period. The coefficients of correlation, derived from Table 5, and used for this purpose, are—

DIURNAL

$r_{G.T} = -.2310$	$r_{T.Tv} = .0538$	$r_{Tv.Hv} = .6974$
$r_{G.Tv} = .5570$	$r_{T.H} = .2847$	$r_{Tv.S} = .5746$
$r_{G.H} = -.0960$	$r_{T.Hv} = -.1184$	$r_{H.Hv} = -.5995$
$r_{G.Hv} = .3800$	$r_{T.S} = .1813$	$r_{H.S} = -.6268$
$r_{G.S} = .0595$	$r_{Tv.H} = -.4095$	$r_{Hv.S} = .4980$

NOCTURNAL

$r_{L.T} = -.3391$	$r_{T.Tv} = -.1282$	$r_{Tv.H} = -.4819$
$r_{L.Tv} = .5136$	$r_{T.H} = -.0113$	$r_{Tv.Hv} = .5034$
$r_{L.H} = -.4821$	$r_{T.Hv} = -.1018$	$r_{H.Hv} = -.9107$
$r_{L.Hv} = .5391$		

Substituting the known values and solving the following simultaneous equations,

$$\begin{aligned} r_{GT} &= a + br_{Tvt} + cr_{HT} + dr_{Hvt} + er_{ST} \\ r_{GTv} &= ar_{TTv} + b + cr_{HTv} + dr_{Hvtv} + er_{STv} \\ r_{GH} &= ar_{TH} + br_{TvH} + c + dr_{HvH} + er_{SH} \\ r_{GHv} &= ar_{THv} + br_{TvHv} + cr_{HHv} + d + er_{SHv} \\ r_{GS} &= ar_{TS} + br_{TvS} + cr_{HS} + dr_{HvS} + e \end{aligned}$$

we have—

$$a = -.26769, b = .74349, c = .16154, d = .04688, e = -.24127$$

Again, substituting these values for the path coefficients in the following formula,

$$p_{GT}r_{GT} + p_{GTv}r_{GTv} + p_{GH}r_{GH} + p_{GHv}r_{GHv} + p_{GS}r_{GS} = 1 - o^2$$

we find—

$$o^2 = .53609$$

Although the same diurnal variables were used in calculating the value of the unknown factors for the fall and spring periods, the values of the unknown factors for these periods are considerably different. There must be other important variables not included in the present data which emphatically influence the changes of colony weight during the fall.

The path coefficients for the nocturnal period during the fall were derived from the solution of the following four simultaneous equations:

$$\begin{aligned} r_{LT} &= a + br_{Tvt} + cr_{HT} + dr_{Hvt} \\ r_{LTv} &= ar_{THv} + b + cr_{HTv} + dr_{Hvtv} \\ r_{LH} &= ar_{TH} + br_{TvH} + c + dr_{HvH} \\ r_{LHv} &= ar_{THv} + br_{TvHv} + cr_{HHv} + d \end{aligned}$$

In this case—

$$\begin{array}{ll} a = -.27206 & c = -.07350 \\ b = .29408 & d = .29642 \end{array}$$

The solution of the equation—

$$p_{LT}r_{LT} + p_{Lrv}r_{Lrv} + p_{LH}r_{LH} + p_{LHv}r_{LHv} = 1 - o^2$$

therefore gives—

$$o^2 = .56148$$

It is interesting to note that the value of the unknown nocturnal factors during the fall is less than it is during the spring. With the same variables in use for calculating the value of o^2 during these two periods, the difference must be accounted for by variation in the behavior of the bees themselves.

The writer has calculated the value of o^2 from the coefficients of correlation which he determined from data by Harrault (15), given under the discussion of temperatures. In this case only two variables are available, namely, the average daily temperature and the relative humidity. The solution of the two simultaneous equations—

$$\begin{array}{l} r_{GT} = a + br_{TH} \\ r_{GH} = ar_{TH} + b \end{array}$$

gives $a = .4779$ and $b = .1635$. By substituting these values in the formula—

$$p_{GT}r_{GT} + p_{GH}r_{GH} = 1 - o^2$$

we have—

$$o^2 = .6998$$

This figure shows the value of the unknown factors to be greater than that found in this work for the spring period.

A similar analysis of Bonnier's (1) data gives $o^2 = .3093$. This figure is lower than that given for the spring period. One must take into consideration that only temperature and relative humidity were considered by Bonnier and that activity of the bees does not enter into consideration in his work.

THEORETICALLY CHANGING WEATHER FACTORS AND PREDICTING RESULTING GAINS

One of the primary objects in presenting the following data is to demonstrate the value of accurately kept records of colony weight, together with weather records. By knowing how changes of colony weight vary with changes in the weather factors over a series of years, it would not be an impossibility to predict whether or not, in the long run, a certain locality would justify commercial beekeeping. Such data could also be used to plan migratory beekeeping and to learn perhaps whether a locality not suitable for honey production would be suitable for the production of bees or for queen rearing.

In order to give concrete examples in predicting gain under any variation of weather conditions, the necessary data may be taken

from Table 6 and given, decoded, in Table 7. The following path coefficients are also used in the computations (see p. 42) for the spring period:

$$\begin{aligned} a = p_{GT} &= .6898 & d = p_{GHv} &= -.2075 \\ b = p_{GTV} &= .0630 & e = p_s &= .1004 \\ c = p_{GH} &= -.3217 \end{aligned}$$

The formula for multiple regression, as given below, is used in arriving at the value of the predicted gain G' :

$$G' = \bar{G} + a\sigma_G \frac{T' - \bar{T}}{\sigma_T} + b\sigma_G \frac{Tv' - \bar{T}v}{\sigma_{Tv}} + c\sigma_G \frac{H' - \bar{H}}{\sigma_H} + d\sigma_G \frac{Hv' - \bar{H}v}{\sigma_{Hv}} + e\sigma_G \frac{S' - \bar{S}}{\sigma_S}$$

This equation, in turn, is simplified to—

$$G' = \bar{G} + k_T(T' - \bar{T}) + k_{Tv} \cdot (Tv' - \bar{T}v) + k_H \cdot (H' - \bar{H}) + k_{Hv} \cdot (Hv' - \bar{H}v) + k_s \cdot (S' - \bar{S})$$

where—

$$\begin{aligned} k_T &= 134.5550 & k_{Hv} &= -18.3968 \\ k_{Tv} &= 11.3678 & k_s &= 30.6658 \\ k_H &= -38.0266 \end{aligned}$$

TABLE 6.—Mean and standard deviations of weather factors and changes of colony weight for the spring period

	Net gain	Noc-turnal loss	Diurnal average temperature	Diurnal variation of temperature	Diurnal average humidity	Diurnal variation of humidity	Hours of sunshine	Solar Radiation	Noc-turnal average of temperature	Noc-turnal variation of temperature	Noc-turnal average humidity	Noc-turnal variation of humidity
Mean-----	3.9209	4.2630	4.6314	4.9472	3.5262	4.6840	5.5787	6.1577	5.4998	4.7103	5.8419	3.8946
σ -----	2.2289	2.2908	2.5385	2.4705	2.2448	2.5140	3.0406	2.6808	2.8169	1.5717	2.0333	2.2687

TABLE 7.—Decoded values of the means and standard deviations of variables used in determining G'

Variable	Mean	σ
G	3023.1600	1114.4500
T	75.8600	5.7116
Tv	25.7300	6.1762
H	55.0700	9.4281
Hv	57.0200	12.5700
S	10.5580	3.6487

By substituting in either of the foregoing equations the various weather factors for each day, as given in Table 8, we obtain the effect, measured in grams, of the individual weather factors upon the gain of any particular day. Table 9 also gives these individual values for all days shown in Table 8.

Using this method, calculations have been made from the weather data shown in Table 8 to determine the predicted gain for each day

of the spring period of the two years. The results of these calculations are presented in Table 10, which also gives the relation of the actual gain to the predicted gain in terms of percentage. It will be noticed that the average of the predicted gains is 100.53 per cent of the average of actual gains. This figure, however, has no biological significance, since all of the predicted gains were calculated on a daily basis.

The correlation between actual gain and predicted gain is theoretically obtained by the following formula:

$$r_{gg'} = \sqrt{ar_{gt} + br_{gv} + cr_{gh} + dr_{ghv} + er_{gs}} = .8080$$

The actual and predicted gains may, therefore, be expected to agree within approximately 20 per cent of each other.

In order to determine how close this calculated correlation agrees with the true correlation between actual and predicted gains, the figures shown in Table 10 were correlated by the usual method for obtaining the coefficient of correlation.

In this case—

$$r = \left(\frac{\sum xy}{n} - \bar{x} \bar{y} \right) \frac{1}{\sigma_x \sigma_y} = .8844$$

These two values, actual, $r_{gg'} = .8844$, and predicted, $r_{gg'} = .8080$, are reasonably close and serve as an excellent check on all the computations involved.

TABLE 8.—*Morning loss, net gain, nocturnal loss, and intensity of weather factors during the spring period, colonies AB and 2, May, 1922 and May, 1923*

Date	Colony number	Morning loss	Net gain	Nocturnal loss	Diurnal average temperature	Diurnal variation of temperature	Hours of sunshine	Solar radiation	Diurnal average relative humidity	Diurnal variation of relative humidity	Nocturnal average temperature	Nocturnal variation of temperature	Nocturnal average relative humidity	Nocturnal variation of relative humidity
1922		<i>Gr'ms</i>	<i>Grams</i>	<i>Grams</i>	<i>° F.</i>	<i>° F.</i>					<i>° F.</i>	<i>° F.</i>		
May 10....	AB	420	980	380	70.8	22	4.8	244.6	78.2	30	68.4	12	97.6	9
11....	AB	240	5,900	700	83.3	31	14.2	637.3	45.4	63	71.3	18	74.0	17
12....	AB	280	2,550	460	70.7	18	6.5	387.2	59.5	44	63.3	9	88.8	23
13....	AB	210	2,410	520	74.6	23	9.1	538.6	53.8	33	66.9	14	94.9	22
14....	AB	150	2,220	660	74.6	22	6.9	461.8	63.2	66	63.2	6	98.3	3
15....	AB	320	1,110	510	73.5	23	10.9	579.6	65.9	55	58.9	13	94.3	23
16....	AB	320	1,670	350	76.4	31	12.5	680.6	44.9	73	66.2	13	79.4	54
20....	AB	150	3,700	420	76.2	28	9.8	655.0	54.7	52	66.9	12	96.3	13
21....	AB	200	3,690	570	80.8	30	10.9	591.2	59.7	62	69.5	11	89.2	20
22....	AB	200	4,610	600	80.7	23	11.4	627.6	62.7	48	68.2	13	96.3	18
23....	AB	240	4,080	610	80.6	26	12.8	541.7	62.3	60	69.0	13	86.3	10
24....	AB	270	3,320	690	80.7	27	14.4	588.2	56.2	47	65.4	19	65.6	44
1923														
May 18....	2	370	3,530	630	72.7	29	8.7	510.7	49.2	62	63.9	12	92.7	21
19....	2	550	3,080	780	76.3	27	14.4	594.1	50.8	70	62.2	11	87.0	32
20....	2	390	3,100	960	75.5	23	8.4	445.6	62.5	50	69.0	3	94.5	8
21....	2	520	3,240	1,080	76.7	14	8.1	502.6	69.7	46	63.6	10	87.4	13
22....	2	590	2,540	890	68.4	17	12.6	660.9	56.7	42	56.3	11	88.2	26
23....	2	460	1,140	480	64.7	17	3.7	301.3	50.7	59	52.5	12	92.4	17
24....	2	150	3,520	740	69.6	32	14.6	653.6	41.2	73	53.6	15	84.0	37
25....	2	110	3,960	980	74.6	37	13.7	661.5	38.0	79	58.6	13	73.9	43
26....	2	130	4,350	840	80.3	35	14.3	672.5	44.0	63	67.1	14	85.6	33
27....	2	70	4,370	820	84.9	34	13.2	597.5	47.8	69	69.3	15	80.6	20
28....	2	170	3,630	810	78.6	28	9.2	484.1	65.9	47	70.6	10	91.3	11
29....	2	80	3,940	800	86.3	32	14.2	562.9	50.1	69	71.6	12	83.8	25
30....	2	510	1,670	580	71.4	12	3.4	263.4	66.5	38	59.6	13	93.3	15

TABLE 9.—Differences between actual temperature, temperature variation, relative humidity, variation of relative humidity, hours of sunshine and their means, and the effect in grams that these deviations have upon the net gains in colony weight of the spring period. The last column gives predicted gain, which is the sum of the effects of individual weather factors upon net gains plus $\bar{G}$

Date	$T' - \bar{T}$	$(T' - \bar{T}) \cdot k_T$	$T_V - \bar{T}_V$	$(T_V - \bar{T}_V) \cdot k_{TV}$	$H' - \bar{H}$	$(H' - \bar{H}) \cdot k_H$	$H' - \bar{H}_e$	$(H' - \bar{H}_e) \cdot k_{He}$	$S' - \bar{S}$	$(S' - \bar{S}) \cdot k_S$	$\Sigma(m' - \bar{m}) \cdot k + \bar{G}$
1922											
May 10.....	-5.06	-680.8483	-3.73	-42.4018	23.13	-879.5552	-27.02	497.0815	-5.758	-176.5736	1,740.8626
11.....	7.44	1,001.0892	5.27	59.9083	-9.67	367.7172	5.98	-110.0128	3.642	111.0848	4,453.5467
12.....	-5.16	-694.3038	-7.73	-87.8730	4.43	-168.4578	-13.02	239.5263	-4.058	-124.4418	2,187.6099
13.....	-1.26	-169.5393	-2.73	-31.0340	-1.27	48.2937	-24.02	441.8911	-1.458	-44.7107	3,268.9608
14.....	-1.26	-169.5393	-3.73	-42.4018	8.13	-309.1562	8.98	-165.2032	-3.658	-112.1764	2,224.6841
15.....	-2.36	-317.5498	-2.73	-31.0340	10.83	-411.8280	-2.02	37.1615	3.342	10.4877	2,310.3974
16.....	.54	72.6597	5.27	59.9083	-10.17	386.7305	15.98	-293.9808	1.942	59.5529	3,308.0306
17.....	.34	45.7487	2.27	25.8049	-.37	14.0698	-5.02	92.3519	-7.758	-23.2446	3,177.8907
20.....	4.94	664.7017	4.27	48.5405	4.63	-176.0631	4.98	-91.6160	.342	10.4877	3,479.2108
21.....	4.84	651.2462	-2.73	-31.0340	7.63	-290.1429	-9.02	165.9391	.842	25.8206	3,544.8890
22.....	4.74	637.7907	.27	3.0693	7.23	-274.9323	2.98	-54.8224	2.242	68.7527	3,403.0180
24.....	4.84	651.2462	1.27	14.4371	1.13	-42.9700	-10.02	184.3359	3.842	117.8180	3,948.0272
1923											
May 18.....	-3.16	-425.1938	3.27	37.1727	-5.87	223.2161	4.98	-91.9160	-1.858	-56.9770	2,709.4620
19.....	.44	59.2042	1.27	14.4371	-4.27	162.3735	12.98	-238.7904	3.842	117.8180	3,138.2024
20.....	-.36	-48.4398	-2.73	-31.0340	7.43	-282.5376	-7.02	129.1455	-2.158	-66.1767	2,724.1174
21.....	.84	113.0262	-8.73	-133.3442	14.63	-556.8291	-11.02	202.7327	-2.458	-75.3765	2,573.8691
22.....	-7.46	-1,003.7803	-8.73	-99.2408	1.63	-61.9833	-15.02	276.3199	2.042	62.6195	2,197.0950
23.....	-11.16	-1,501.0338	-8.73	-99.2408	-4.37	166.1762	1.98	-36.4256	-6.858	-210.3600	1,341.7300
24.....	-6.26	-842.3143	6.27	71.2761	13.87	527.4289	15.98	-293.9808	4.042	123.9511	2,609.5210
25.....	-1.26	-169.5393	11.27	128.1151	-17.07	649.1140	21.98	-404.3616	3.142	96.3519	3,322.8401
26.....	4.44	597.4242	9.27	105.3795	-11.07	420.9544	5.98	-110.0128	3.742	114.7514	4,151.5514
27.....	9.04	1,216.3772	8.27	94.0117	-7.27	276.4533	11.98	-220.3836	2.642	81.0190	4,470.0276
28.....	2.74	368.0807	2.27	25.8049	10.83	-411.8280	-10.02	184.3359	-1.358	-41.6441	3,148.5094
29.....	10.44	1,404.7542	6.27	71.2761	18.87	188.9922	11.98	-220.3836	3.642	111.0848	4,579.4742
30.....	-4.46	-600.1153	-13.73	-156.0798	11.43	-434.0440	-19.02	349.9071	-7.158	-219.5057	1,962.7223

TABLE 10.—*Actual and predicted gains and percentage of actual gain to predicted gain in colony weight for the spring period*

Date	Actual gain	Predicted gain	$\frac{G'}{G} \times 100$	Date	Actual gain	Predicted gain	$\frac{G'}{G} \times 100$
1922				1923			
May 10.....	980	1,740	177.55	May 18.....	3,065	2,709	88.38
11.....	5,900	4,453	75.47	19.....	2,750	3,138	114.10
12.....	2,550	2,187	85.76	20.....	2,850	2,724	95.57
13.....	2,410	3,268	135.60	21.....	2,940	2,573	87.51
14.....	2,220	2,224	101.09	22.....	2,295	2,197	95.72
15.....	1,110	2,310	208.10	23.....	1,000	1,341	134.10
16.....	1,670	3,308	198.08	24.....	3,100	2,609	84.16
20.....	3,700	3,177	85.86	25.....	3,470	3,322	95.73
21.....	3,690	3,479	94.28	26.....	3,925	4,151	105.75
22.....	4,610	3,544	76.87	27.....	4,230	4,470	105.67
23.....	4,080	3,403	83.40	28.....	3,680	3,148	85.54
24.....	3,320	3,948	118.91	29.....	4,250	4,579	107.74
				30.....	1,765	1,962	111.16
				Total.....	75,560	75,964	100.53

To take specific days as examples, on May 14, 1922, the actual gain was 2,220 grams and the predicted gain for that day was 2,224 grams. By arbitrarily making relative humidity and the variation of relative humidity equal to the average of these factors, increasing the hours of sunshine from 6.9 to 14.2, and allowing the other weather factors to remain as they were, the predicted gain would be 2,928. Thus the changing of these three weather factors theoretically resulted in a gain of 704 grams.

On May 23, 1923, the net gain is low in comparison with the other days, being 1,000 grams. From the standpoint of the maximum changes of colony weight, the following ideal weather factors were substituted for those actually found on this date:

Hours of sunshine 14.6 hours, instead of 3.7.

Average diurnal temperature 86° F., instead of 64.7° F.

Average relative humidity 38 per cent, instead of 50.7 per cent.

The remaining weather factors were not changed. Under such conditions, the predicted gain is 5,025 grams. The actual predicted gain with existing weather factors on May 23 is 1,341 grams. By changing the weather factors, a predicted net gain of 3,684 grams results. The weather factors here substituted actually occurred within a few days of the 23d of May and so are not at all unreasonable. The combination of optimum conditions occurring all on the same day is, of course, entirely problematical; these examples are given, however, merely to show the importance of the various weather factors on changes of colony weight.

CONCLUSIONS

Although the weather is beyond the control of the beekeeper, a knowledge of the influence of weather factors upon honey crops in various parts of the country will be of great value in developing the best beekeeping regions of the United States.

To gain this knowledge it is first of all necessary to keep certain colonies under observation, recording at frequent and regular intervals the weight of each, and recording such accompanying phenomena of the weather as may reasonably be supposed to influence either the secretion of nectar or the activities of the bees.

A confirmation of the practical value of carefully kept records of this sort is shown by their use in computing predicted changes of colony weight.

A mathematical analysis is necessary to show the true relationship between these changes and the attendant weather factors, and without such mathematical analysis the relative importance of various weather factors upon the changes can not be shown.

Correlations have been made between the changes in the weight of two colonies of bees during the various periods of the day and several weather factors. From the standpoint of the results of these comparisons the most important weather factors of those included in this investigation affecting net gain during the spring period, and, in order, the values of their coefficients of correlation, are, average temperature, .7529; hours of sunshine, .6124; temperature variation, .5967; solar radiation, .5525; variation of relative humidity, .4229; and average relative humidity, -.3806.

Weather factors have but little influence upon nocturnal loss during the spring period, the coefficients of correlation being, temperature variation, -.3439; average temperature, .1754; average relative humidity, -.1264; and variation of relative humidity, -.0654.

During the fall period diurnal changes in colony weight were differently influenced by weather factors, the coefficients of correlation between these changes and the several weather factors being, for temperature variation .5570, variation of relative humidity .3800, average temperature -.2310, average relative humidity -.0960, hours of sunshine .0595, and solar radiation -.0341.

During the fall period the influence of the weather factors upon nocturnal loss was greater than in the spring, the coefficients of correlation being, for variation of relative humidity .5391, variation of temperature .5136, average relative humidity -.4821, and average temperature -.3391.

The importance of the unknown factors influencing net gain during the spring period was less than that of the unknown factors influencing diurnal changes in the colony weight during the fall, the value of the former being .3470, while that of the latter was .5360.

For the spring period the value of the unknown factors upon nocturnal loss was .7026, while that for the fall period was .5614.

Factors influencing the secretion of nectar probably do not similarly influence changes in colony weight.

The changes in the weight of two colonies of bees placed side by side continuously resembled each other.

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UNITED STATES DEPARTMENT OF AGRICULTURE



DEPARTMENT BULLETIN No. 1346



Washington, D. C.

August, 1925

STATUS OF THE PRONGHORNED ANTELOPE, 1922-1924

By

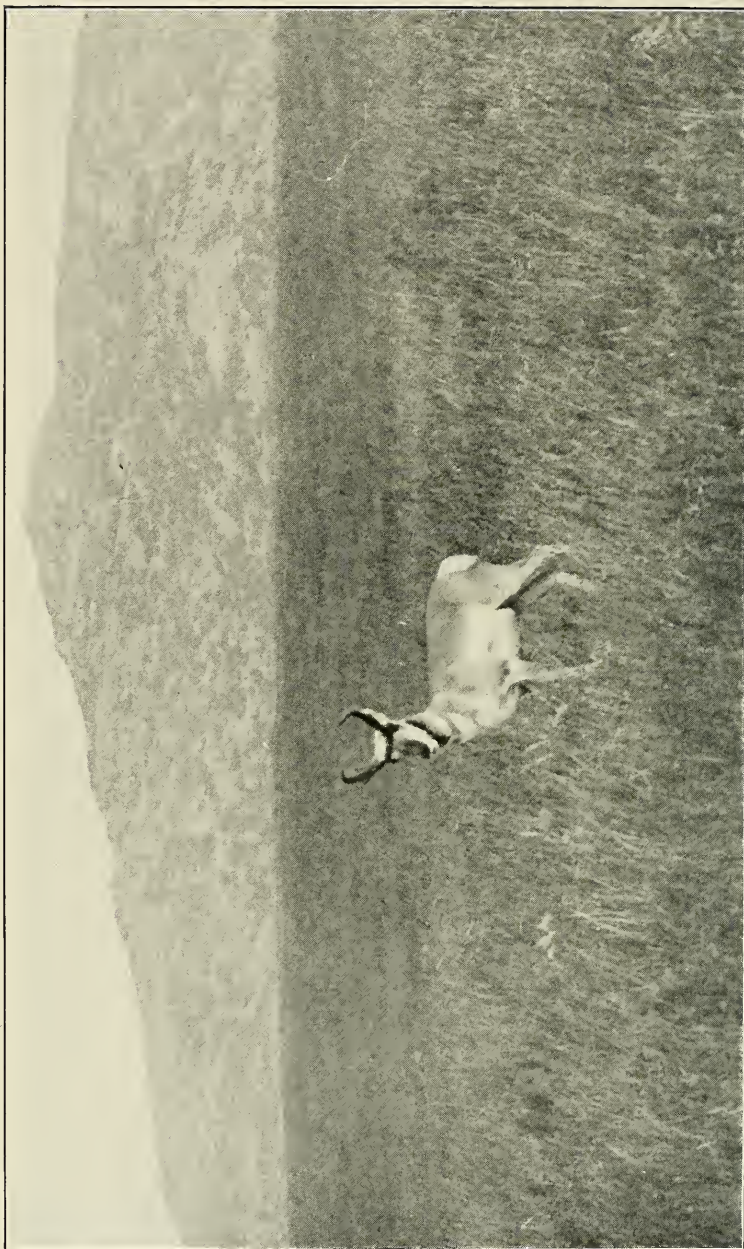
EDWARD W. NELSON, Chief, Bureau of Biological Survey

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BUCK ANTELOPE ON WICHITA GAME REFUGE, OKLA.

The last survivor of a band of nine brought from the Yellowstone Park in 1910-11 by the Boone and Crockett Club and the Forest Service. Additional antelope were introduced from Alberta in 1921 and 1922 by the American Bison Society. The herd now numbers 17, including 12 fawns born on the refuge in 1923 and 1924.

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THE PRONGHORNED ANTELOPE

The pronghorn, or American antelope (*Antilocapra americana*), is the most beautiful and graceful of America's big-game animals and has the distinction of being the only species of antelope existing in the New World at the time of its discovery by Europeans. It is not closely related to the antelopes of the Old World; but, as in the case of many other species of American mammals and birds, it was named by the early settlers from its general resemblance to the well-known Old World group. It is apparently of American origin, as shown by fossil remains of related forms. In addition, remains of species belonging to the true antelopes once inhabiting this continent have been found in fossil beds from coast to coast, some of which show remarkably close affinity to still-existing African types.

FORMER AND PRESENT ABUNDANCE OF PRONGHORNS

The first record of the pronghorned antelope having been seen by Europeans was published in 1723 in Torquemada's *Monarquía Indiana*,¹ in which is described a great hunt made in honor of the viceroy, Antonio Mendoza, in 1540, at a place in the extreme southwestern part of the State of Hidalgo and adjoining parts of the

¹ Vol. 1, book 5, pp. 611-612.

State of Mexico. The plain on which this hunt occurred has been known from that day to the present as the Llano del Cazadero, in commemoration of this event. The station of Cazadero on the main line of the Mexican Central Railroad marks this vicinity.



FIG. 1.—Original and present distribution of the pronghorned antelope. The black line marks the limits of the distribution before European settlements in America. The shaded portion indicates the area within which antelope are now found (1922-1924) in scattering bands. Details of present distribution within this area are shown on separate maps of States and Provinces (figs 3 to 21), and in Table 1, page 3

The hunt took the form of a great drive of game by the Indians, during which, the author states, 600 deer were killed, among which were large stags "and those which they call verrendos." He states that the verrendos did not occur in Spain, and that "they not only ran but flew," thus indicating that the remarkable speed of these

animals attracted the attention of the first European observers. Throughout the antelope country in Mexico and the southwestern United States the Mexicans still term these animals "berrendos," the "v" of the old Spanish having been replaced by the modern "b." As a matter of course the pronghorn must have been a familiar animal to the hardy Spaniards, who overran all parts of Mexico and much of the southwestern and western United States in their search for gold, but their records of the animal life seen are exceedingly scanty.

Subsequent occupation of the continent has shown that the pronghorn ranged over an enormous area. (See map, fig. 1.) It occurred over parts of the present Provinces of Manitoba, Saskatchewan, and Alberta, in Canada. In the United States it occupied the country from western Minnesota, Iowa, Kansas, Oklahoma, and Texas, reaching the Gulf coast near the mouth of the Rio Grande, and west to eastern Washington, Oregon, and the Pacific coast in California. In Mexico it occupied the open plains country of the tableland south almost to 20° of latitude, nearly to the Valley of Mexico; also the western part of Sonora and most of Lower California.

TABLE 1.—*Distribution of antelope in North America, 1922-1924*

Region	Areas	Number of antelope	Region	Areas	Number of antelope
Arizona.....	18	651	Canada:		
California.....	6	1,057	Alberta.....	5	1,030
Colorado.....	28	1,233	Saskatchewan.....	9	297
Idaho.....	14	1,485	Total, Canada.....	14	1,327
Kansas.....	1	8	Mexico:		
Montana.....	44	3,027	Coahuila ¹	1	600
Nebraska.....	10	187	Chihuahua ¹	1	700
Nevada.....	11	4,253	Durango.....		(?)
New Mexico.....	31	1,682	Sonora.....	4	595
North Dakota.....	5	225	Lower California ¹	2	500
Oklahoma.....	2	23	Total, Mexico.....	8	12,395
Oregon.....	4	2,039	Summary:		
South Dakota.....	11	680	United States.....	264	26,604
Texas.....	42	2,407	Canada.....	14	1,327
Utah.....	10	670	Mexico.....	8	12,395
Wyoming.....	27	6,977	Grand total.....	286	30,326
Total, United States.....	264	26,604			

¹ Estimated.

Through the occupation of its territory by man the pronghorn has become extinct in many of its former haunts, but it has survived in limited numbers over an amazing proportion of its original range in Canada, Mexico, and in 16 of the western States of this country.

Originally over most of the enormous territory occupied the pronghorn was very abundant. Its range covered not only practically all of the buffalo country west of the Mississippi River but a vastly greater area. Where the pronghorn occurred with the buffalo people best qualified to judge consider that it exceeded that animal in numbers. It has been estimated that the buffalo herds at one time numbered from thirty to sixty million animals. In view of the greater territory occupied by the pronghorn and its known abundance, it may be considered a conservative estimate to place its probable origi-

nal numbers at not less than thirty to forty millions, and possibly more.

George Bird Grinnell informed the writer that he has often talked about the abundance of antelope with men familiar with the western plains 50 years or more ago and has never met a man of experience who did not agree with him that during the middle of the last century antelope were far more abundant than buffalo. During the summer of 1879 Doctor Grinnell found them extremely abundant in North Park, Colo., where he saw trails made by them in travel from one locality to another worn in the hard soil to a depth of from 8 to 10 inches, like the trails made by buffalo herds going to and from water or during their movements from one district to another.

As against the many millions of pronghorns once inhabiting this continent a recent census, taken through the Biological Survey and detailed elsewhere, shows approximately 30,000 survivors. (See Table 1, p. 3.)

CHARACTERISTICS OF THE AMERICAN ANTELOPE

Horns.—The pronghorn is the only antelope in the world with branched or pronged horns, and has the unique characteristic among all hollow-horned ruminants of shedding the outer covering of the horns annually. This takes place soon after the rut in November and December in the Yellowstone National Park in northern Wyoming, and elsewhere in the range of the species this time probably varies somewhat with latitude.

When the time for shedding arrives the horny sheath gradually loosens and becomes detached from the skin around the base and, following this, from the bony core within. Later the horn falls off, leaving the bony core covered with a blackish skin more or less overgrown with long, coarse hairs, which afterward are gradually lost. A new horny nucleus develops on the tip of the bony core, the horny growth then extending slowly downward until it reaches the base. Gradually thickening and hardening, the horny material grows at the tip until the new horn attains its full development. The horns continue to grow as the animal increases in age until the full size is reached.

Both sexes have horns, those on the does being smaller and slenderer than on the bucks.

Rump patch.—Another characteristic of these interesting animals is a conspicuous rump patch composed of white hairs which are longer than those elsewhere on the animal's back. Through developments in the skin muscles the pronghorn at times of excitement has the power to erect these white hairs until they stand out stiffly over the rump, forming a great dazzlingly white rosette, like a giant chrysanthemum, which, when the animal is dashing away across the plains in the bright sunlight, is extraordinarily conspicuous. The writer has many times discovered bands of antelope running on the open plains where but for these heliographic patches they would have been beyond ordinary eyesight. These long rump hairs lie like other hairs on the skin and give little indication of their strikingly conspicuous appearance until the animal suddenly throws them up into action. The antelope fawns at a very early age

begin "flashing" their white rump patches on being startled or excited.

Curiosity.—In addition to its physical peculiarities the pronghorn is very different psychologically from any other of our large-game animals. Early in their acquaintance with these animals hunters became familiar with their intense curiosity, and have employed various methods to toll them within gunshot. One of these was to lie on the ground and wave a red flag slowly back and forth on a ramrod. Another strange performance often said to have the same effect was for a hunter to lie on his back and kick his heels in the air.

While in Mexico some years ago, during the Biological Survey zoological explorations, the writer located a considerable number of antelope on the grassy plains of northwestern Chihuahua, but found them so shy from being hunted in these open spaces that they were almost impossible of approach within gunshot. Specimens were needed for the bureau's scientific study series and every effort was made to secure them—at first, owing to the shyness of these animals, almost without success. Finally, recalling old stories of the curiosity of the antelope, the writer tried the experiment of taking a white bed sheet and, placing one edge over his head, fastened it under his chin. This formed a kind of hood, and when the two upper corners were passed under his arms and attached at the middle in the back, and the hanging edges fastened in front of his body, the whole formed a kind of hooded cloak completely covering him from head to foot. A lot of long grass stems were then gathered and stuck through his hatband so to form a tall, grassy crown.

Covered with this white cloak the writer rode out on the plains until he located a band of antelope, and when at a distance of nearly half a mile dismounted, hobbled his horse, and proceeded toward them in a stooping posture. Meanwhile they were standing looking fixedly at him. When he came within 500 yards he went on his hands and knees, the sheet covering him to the ground, and began moving slowly toward them. The antelope had lined up, with a large buck standing in front. They turned several times and nervously ran a short distance and then turned and raced back to their first position, where they lined up to look at the strange object. The old buck of the band, which from the beginning had stood out by itself in front, began slowing walking toward him. The writer then stopped and sat with crossed legs, the cloak still hiding his person, and waited, rifle in hand, until the buck had come within 100 yards, when it became a prize for the bureau's scientific collection.

On another occasion, while clad in the same disguise, the writer saw a solitary old buck antelope standing about half a mile away on the far side of a bare, dry, alkali mud flat. He again dismounted and made a similar approach, the buck meanwhile standing and watching him steadily. The buck remained motionless and permitted the writer to continue to approach until within about 100 yards without showing any sign of alarm.

Another solitary buck grazing on an open grassy plain was approached in the same manner. Whenever it stopped grazing and looked at him intently, the writer moved his head up and down and

sidewise as though feeding on grass and looking about and then continued to advance on hands and knees. Finally the animal stopped grazing, and when the writer was well within 100 yards it actually closed its eyes and appeared to be dozing, as its head nodded slightly up and down, apparently in complete indifference.

Through the use of this sheet the writer had no trouble in approaching antelope anywhere on the plains, and he was inclined to think that they took him for some harmless white animal. There were many half-wild cattle grazing on these plains at that time which were ordinarily shy and would run away when a man appeared on horseback. After the writer began wearing this white sheet, which not only covered himself but when on horseback would spread over the rump of the horse, the cattle ceased to show any alarm as he appeared and would permit him to ride through herds of them, merely lifting their heads and gazing at him for a short time and then resuming their feeding, the effect of the disguise apparently being the same with them as with the antelope.

It may be of interest to know that the specimens of antelope secured by the use of this grotesque disguise formed the basis of Doctor Merriam's description of a new geographic race of the pronghorn, which he named *Antilocapra americana mexicana*.²

Racing.—One of the most extraordinary peculiarities in the psychology of the pronghorn is its desire to pass in front of a mounted man or a team moving by at no great distance from a band. From 1883 to 1888 the writer lived in a section of Arizona where antelope were plentiful, and frequently hunted them and often saw them when riding in a wagon or on horseback along roads or trails crossing their haunts. This area was mainly covered by a great scattered forest of pinyons, cedars, and junipers, interspersed with many small grassy parks of varying size. During the summer antelope were distributed in small bands in these parks, sometimes 2 or 3 individuals together and at other times from 15 to several times that number.

It was a common occurrence when a traveler passed along these roads for a band to stand from 75 to 200 yards away watching him. Then they would suddenly start and run one after the other parallel to the course taken by the traveler and dash across the road immediately in front of him, often within a short distance, after which they would stream away and disappear among the scattered tree growth. When traveling on horseback and happening upon antelope in such places the writer often amused himself by spurring his horse to a gallop and continuing his course in a direction which would take him by and away from the animals. At such times he tried to appear unconscious of their presence, and this procedure almost invariably brought the expected response, and the animals began racing him until they had gained a slight leadership, when they would dash by in front across the road or trail, one after the other, frequently the last of the lot being within 20 yards.

Once the writer tried the experiment when he saw a solitary buck antelope stand about 100 yards to one side of a wagon road. Appearing not to notice it, he spurred his horse at full speed across

² Proc. Biol. Soc. Washington, vol. 14, p. 31, 1901; type from Sierra en Media, Chihuahua, Mexico.

the level plain. The buck immediately whirled and began racing him over the grassy park, gradually drawing in until it finally crossed the trail almost under the horse's nose and certainly not more than 10 feet away, after which it dashed off and disappeared in the neighboring scattered growth of cedars.

On another occasion, after a long hunt, the writer was returning to camp just as it was becoming too dark to distinguish objects at a distance. Camp was some miles away, and in order to get there quickly he was galloping his horse down the middle of a long, narrow park in the scattered pinyon and cedar forest. He was paying no attention to anything except what lay immediately in front until a curious sound at his right caused him to look, and there he made out the dim forms of a band of about 20 antelope which, in a long line about 30 yards away, were racing him down the park. Eventually they gained sufficient headway to cross his course a short distance in front, when they disappeared. It was so dark at the time that their forms could be only dimly seen.

In discussing the pronghorn with many hunters who have been familiar with it in early days the writer has noted that without exception they have accounts illustrating the extraordinary and apparently overwhelming curiosity of these animals. This very frequently has led the animals to expose themselves to the most imminent danger. They sometimes would come almost into the midst of a camp to satisfy themselves as to the strange beings who had suddenly appeared in their territory, and many fell victims to this habit.

CHOSEN HABITAT

The natural home of the pronghorn was on the treeless, grassy, and often desert plains of the continent. The animals would scatter singly or in small bands in spring and summer, especially during the period when the does were caring for their young fawns. As winter approached they began to gather in bands, sometimes containing thousands of individuals, and to seek favorable feeding grounds for the winter. A band of more than 500 frequented a broken and open pinyon and cedar forest in the part of eastern Arizona where the writer lived in the early eighties. In summer they broke up and scattered over the more open plains in the adjacent parts of New Mexico and northern Arizona. Numbers of them continued to reside through the year among the pinyon and cedar forests, but the bulk of the band went out on the grassy plains. In winter they were very fond of gathering in the pinyon and cedar forests, where they were sheltered from the cold storms which made the open plains places of discomfort. When within these scrubby sheltering forests they were especially liable to become victims of predatory animals and hunters. Near the base of the Sandia Mountains, in New Mexico, the writer knew of hunters trailing bands of antelope among the pinyons during long-continued snow storms and killing many of them one after the other. The animals thus falling victims to the hunter would be roughly dressed and hung up in a pinyon tree, and then the hunter would resume the trail of the survivors and in a comparatively short distance again overtake them and obtain another victim. In this way as many as 10 or 12 could be killed at times during a single morning.

During the eighties the increase in the cattle business was so great in northern Arizona that the antelope learned many new habits. Among others was that of following range cattle through a belt of heavy pine forest up to an elevated grassy plateau of about 8,000 feet altitude, lying on the east front of the White Mountains, about the headwaters of the Black, Blue, and Colorado Rivers. There, on a wide rolling open plain, they passed the summer, coming out, on the approach of winter, in company with the cattle. This change was comparable to that which caused the elk, once a habitant of the foothills and adjacent plains, to become an animal of the higher elevations. During this period antelope became frequenters of the open, grass-grown, yellow-pine forests of the mountain areas not only in various parts of the United States but also in the Sierra Madre of Chihuahua, Mexico.

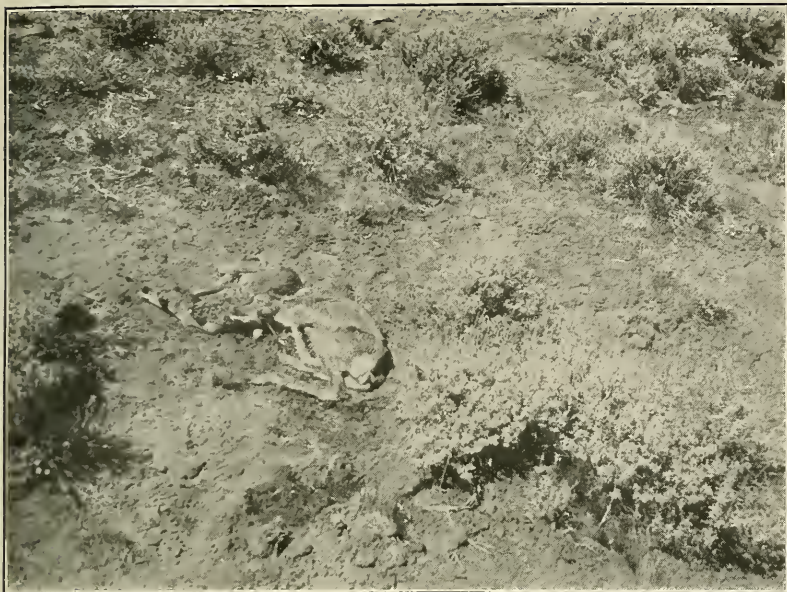
CONSERVATION AND CONTROL

The hunting of antelope is now forbidden by law almost throughout its range. In the United States, of the 16 States in which these animals still occur, Wyoming is the only one in which their hunting might be legalized. The Wyoming law authorizes the State game and fish commission to permit the killing of not to exceed 100 bucks in designated parts of the State from September 15 to October 31 in any year. In 1922 the Wyoming commission had in mind to permit the killing of 100 buck antelope under the terms of this law, but the opposition expressed by individuals and in the press, not only in Wyoming but in other parts of the country, caused the plan to be abandoned. In 1925, however, the legislature authorized the issuance of 300 such permits during October, in certain counties in the eastern and southern parts of the State.

In Nevada the close season ends in 1930, and in Kansas, by action of the 1925 legislature, the close season was extended indefinitely.

There is little likelihood that the season will be opened in any other States in the near future, although under good protection the increase of antelope in favorable areas may in a few years render it urgently necessary to reduce their numbers. With the increasing occupation of the western United States, the presence of antelope in such numbers as might occur under complete protection might create a situation that would be intolerable to some of the residents whose livelihood depends upon farming and grazing.

Antelope, as in the case of other large-game animals, when under practically complete protection, lose their fear of man to a surprising extent and become bold in raiding fields and in destroying crops. The possibility of the development of such conditions should be seriously considered by conservationists in building up herds of antelope. Efforts should be made to seek, for the establishment of antelope refuges, remote and thinly settled areas unless the animals are to be reared within fenced inclosures. Even in the latter case the increase of the animals will eventually require some control of the numbers by eliminating the surplus. This is a matter of practical game administration which should be understood and accepted by the public with the same matter-of-course attitude that is shown toward the control of the surplus livestock on a farm. The limited hunting-license system provides a practical method of handling sur-



B2499M

FIG. 1.—TWO NEWLY BORN ANTELOPE, DIESSNER RANCH, NEV.

The doe usually hides the fawns one in a place and, feeding unconcernedly, approaches to nurse them. By watching the mothers the young animals are located and captured



B2502M

FIG. 2.—FAWNS JUST CAPTURED, WASHOE REFUGE, NEV.

As soon as captured, the fawns are placed in grain sacks, each with a hole in it just large enough for the head to be put through. One sack is then hung on each side of a saddle horse and the fawns are brought to camp



B2505M

FIG. 1.—YOUNG ANTELOPE IN TEMPORARY INCLOSURE

Captured on the Washoe Game Refuge and raised on the Wood Ranch, near Diessner, north-western Nevada, by E. R. Sans, of the Biological Survey. Photograph taken July 18, 1924



B2503M

FIG. 2.—BOTTLE-RAISED FAWNS

Photograph taken in August, 1924, on the Wood Ranch, near Diessner, Nev.

plus game and at the same time perpetuating the species in reasonable numbers.

Conservationists should appreciate that there must be a sympathetic attitude on the part of the general public which is in direct contact with the game. This means that the surplus of big game, either of antelope or of any other kind, must be disposed of in a practical way, leaving a reasonable breeding stock to perpetuate the species. Those having administrative charge of the game in any area should determine the number of each species of large game that can properly be maintained there and provide for eliminating the surplus, if any, each year. In this manner overstocking the range and other embarrassments may be avoided.

The number of game animals of each species to be maintained in each area should be determined by a careful study of the conditions in the area by trained experts having practical knowledge of the requirements of the different species. It should be clearly understood that at the present time and for some years to come antelope need strict protection practically throughout their range, the one probable exception being in a limited area in Wyoming.

CONSERVATION ORGANIZATIONS AND THE ANTELOPE

A number of leading organizations of the country have interested themselves definitely in the conservation of antelope during a period of years. This is an appropriate place to put on record the more notable achievements of these organizations up to this time.

Boone and Crockett Club.—The last of December, 1910, and the first of January, 1911, 3 buck and 6 doe antelope were obtained from the Yellowstone National Park herd by the Boone and Crockett Club and shipped to the Wichita National Game Preserve in Oklahoma, in cooperation with the United States Forest Service. (See Pl. I.) During this period 4 bucks and 8 does from the same source were shipped by this club to the National Bison Range in Montana, in cooperation with the Biological Survey. Of the antelope sent to Oklahoma, some reached their destination dead and others badly injured, and eventually all died. Those sent to the Bison Range were the basis of a herd of 64 animals which was subsequently built up and then completely destroyed by the inroads of predatory animals.

During 1914 the Boone and Crockett Club purchased 13 antelope in Alberta, which were sent to the Wind Cave National Park and Game Preserve in South Dakota. These animals did well for a time, but later their numbers had become so reduced that in 1916 the club again purchased 9 antelope in Alberta, which were placed in the same game preserve. Here they did well for a time and increased to 34 animals. Most of these were afterwards destroyed by predatory animals, but enough still remain to serve as a nucleus for building up a new herd. Special efforts are being made to protect them from further attacks by predatory animals. (Pl. VI.)

The Boone and Crockett Club appears to have been the pioneer in this line of conservation.

American Bison Society.—In January, 1912, the American Bison Society first became interested in the future of the antelope and assisted in an attempt to pass a bill through Congress to create the

Snow Creek Antelope Preserve in Montana. In 1919 M. S. Garretson, secretary of this society, accompanied a representative of the Biological Survey to investigate conditions in southeastern Oregon for the purpose of determining the suitability of the region for the establishment of a Federal antelope refuge.

In October, 1921, the society purchased in Alberta and delivered at the Wichita National Game Preserve, Okla., 10 young antelope for the purpose of again trying to establish a herd in this locality. Most of these perished, and in 1922 the society purchased 6 additional antelope in Alberta, which were delivered at that game preserve. Most of these died; but, as is set forth in detail in the account of antelope in Oklahoma, this herd is at last increasing, with a good prospect that it may become permanently established.

During the spring of 1921 the secretary of the society accompanied a representative of the Biological Survey on an expedition to southwestern Idaho to examine that district to make recommendations concerning the establishment there of the Owyhee Antelope Refuge. The same year funds were contributed by the society to assist in protecting the Mount Dome antelope herd in California.

The annual report of the American Bison Society for 1922-23, pages 49 to 51, contains the first published census of the antelope of North America, which is dated January 1, 1922. This census was compiled by M. S. Garretson, secretary of the society, and gave a total of 11,749 antelope for the United States and Canada. The census of antelope compiled by the Biological Survey and given in detail later in this publication indicates a much greater number of antelope surviving than given in the first census mentioned above. Mr. Garretson's very creditable work was handicapped by many difficulties. The greater completeness of the census of the Biological Survey is due to the fortunate fact that this bureau has a number of employees permanently located in each of the several States where antelope occur.

The Bison Society has taken the stand that, having assured the perpetuation of the bison, it is free to help save the antelope now approaching a condition which will require active work to prevent their extermination.

Permanent Wild-Life Protection Fund.—The Permanent Wild-Life Protection Fund throughout its existence has taken an active interest in the conservation of antelope and has contributed substantial sums to carry out this purpose in various parts of the country. It contributed to the Bison Society funds in connection with investigations to create a Federal antelope refuge in southeastern Oregon, also for the establishment of a herd of antelope in the Wichita National Game Preserve, and for the protection of the Mount Dome herd in California. In cooperation with E. E. Brownell and the Biological Survey it assisted in the capture of 40 young antelope in northwestern Nevada during the spring of 1924 and in their distribution to the Grand Canyon National Park, Ariz.; to the Niobrara Federal Game Refuge, near Valentine, Nebr.; and to the National Bison Range, in western Montana. It has also contributed funds to cooperate with the Biological Survey in marking the boundaries of the Washoe and Humboldt Antelope Refuges in northern Nevada. It has contributed special rewards for convictions for illegal killing of

antelope in Oregon, and is cooperating with the Mexican Government in maintaining a special warden service to protect antelope and mountain sheep in northern Sonora. There the Mexican Government has appointed Ben H. Tinker, of Arizona, an honorary game guardian for northern Sonora. He entered on this duty on October 1, 1923, and patrols the Arizona-Sonora border during the active hunting season, October 1 to April 1, in order to enforce an executive decree protecting antelope and mountain sheep for a period of 10 years.

California Associated Societies for the Conservation of Wild Life.—This organization has interested itself in the perpetuation of the Mount Dome antelope herd. It is working with the State board of fish and game commissioners and has provided funds for feeding the animals during severe winters. It began its operations in 1914, and among its other activities materially helped in gathering information for this report concerning the distribution of antelope throughout California.

WASHINGTON CONFERENCE ON THE CONSERVATION OF THE PRONGHORN

For some years suggestions had been made that a conference be held to consider the conservation of antelope, the earlier proponents being E. Lester Jones, Director of the Coast and Geodetic Survey, Department of Commerce; Edmund Seymour, president of the American Bison Society; T. Gilbert Pearson, president of the National Association of Audubon Societies; and others.

In view, however, of the fact that a census of these animals was being taken by the Biological Survey, it was deemed best to delay such a conference until this investigation had been concluded, in order that the information obtained might be available for consideration. This census was practically completed in the fall of 1923, and a call for the antelope conference was issued by the chief of the Biological Survey to meet in the auditorium of the New National Museum, in Washington, D. C., December 14, 1923. The meeting was attended by representatives of the principal wild-life-conservation organizations of the country, State game wardens from a number of States, representatives of Government bureaus interested in wild-life conservation, and numerous private individuals. The conservation organizations and their representatives were:

Boone and Crockett Club, by Charles Sheldon; American Bison Society, by Edmund Seymour and W. T. Hornaday; Permanent Wild Life Protection Fund, by W. T. Hornaday; National Association of Audubon Societies, by T. Gilbert Pearson, W. P. Wharton, and William Finley; American Game Protective Association, by John B. Burnham; Izaak Walton League, by Will H. Dilg; Game Conservation Committee of the Camp-Fire Club of America, by W. B. Greeley and Marshall McLean; Associated Societies for the Protection of Wild Life in California, by Alden Sampson; and the National Parks Association, by Robert Sterling Yard.

Registration was made of the following State game commissions, represented by their chiefs:

Arizona, G. M. Willard; Arkansas, Lee Miles; California, F. M. Newbert; Kansas, J. B. Doze; Massachusetts, W. C. Adams; Minne-

sota, J. F. Gould; Pennsylvania, the executive secretary, Seth E. Gordon.

The interest of the Federal Government in the conservation of the pronghorn was shown by the presence of Senator Peter Norbeck, of South Dakota, and by representation from the following Federal bureaus:

National Park Service, the director, Stephen T. Mather; Forest Service, W. C. Barnes and E. N. Kavanaugh; Coast and Geodetic Survey, the director, E. Lester Jones; and the Biological Survey, by the chief and several members of the staff. The Canadian National Parks Service, at the request of J. B. Harkin, commissioner, was also represented, O. S. Finnie, director, Northwest Territories Branch, Department of the Interior, being present.

The results of the census which had been practically completed by the Biological Survey were presented. These are set forth with some additions elsewhere in this bulletin.

From time to time during the past years the desirability has been suggested of organizing a national antelope society to foster the conservation of the pronghorn. In view of the fact that a number of the more important conservation organizations had already interested themselves and expended considerable money on projects for this purpose, it appeared to the conference that the organization of an additional conservation society would probably result in complications not beneficial to the cause and might really act as a deterrent to the development of much-needed activity to save these beautiful animals from extermination. It was agreed that the existing conservation organizations should continue to interest themselves in the conservation of the antelope as opportunity offered, and that whenever one organization should take up a specific project the others would actively cooperate in carrying it to a successful conclusion.

It was further agreed that the Biological Survey should serve as a clearing house for information concerning the pronghorn, and that its cooperation should be utilized as fully as possible in this work. The location of the Biological Survey field men engaged in predatory-animal and rodent-control work in all of the States in which antelope still exist places this bureau in a specially favorable position to procure up-to-date information on the subject. To put this decision into definite form Marshall McLean proposed a resolution for the purpose of establishing continuity of interest and activity, which was unanimously adopted by the conference, as follows:

That individuals and organizations represented here or others desiring to take part constitute themselves a conference for the preservation of antelope with the object of cooperating with the Biological Survey to that end.

After a discussion of many details and phases of the antelope situation and of matters connected with their conservation, T. Gilbert Pearson presented L. D. Frakes, owner of a cattle ranch near Warner Lake, and J. L. Lyon, owner of a sheep ranch near Lakeview, in southeastern Oregon, who came to the conference for the purpose of advocating the establishment of an antelope and sage-hen refuge covering a large area in southeastern Oregon. They announced that their ranches lie within the proposed refuge and that

up to within a year they had been strongly opposed to its establishment: but that, after studying the matter carefully and learning the facts as to the policies that would be followed by the Government, they had become convinced that such a refuge would be to the advantage of the residents of that section of Oregon, as well as to the antelope and other wild life there.

In the discussion with these stockmen it developed that in the period when they were opposing the establishment of the refuge they believed that it would involve the elimination of livestock within the area and the destruction of their interests; but when it was understood that if such a refuge should be established there would be no elimination of the livestock of resident stock growers or other interference with their freedom beyond that of stopping the shooting of game within the area and the limitation of the number of livestock to the capacity of the forage production of the range, they approved the plan.

After discussion of the suggested antelope refuge in southeastern Oregon the conference adopted a resolution authorizing a committee made up of representatives of the conservation organizations present to meet in the offices of the Biological Survey during the afternoon of December 14 to confer with those interested and draft a bill for the creation of an antelope and sage-hen refuge in southeastern Oregon. Since then a bill has been introduced in the Oregon Legislature for the establishment of a State antelope refuge covering the area recommended.

The exclusion of hunters from the area and the prevention of destructive overstocking cover the only restrictions contemplated in the proposed Federal refuge. It was planned that the control of the grazing should be under the supervision of the Forest Service, in order to provide for the best utilization of the forage practicable.

It will be of interest to know that the first suggestion for establishing an antelope refuge in southeastern Oregon appears to have been made by L. Alva Lewis, an agent of the Biological Survey, in a letter dated January 22, 1913. In October of the same year Harry Tilford, inspector of State game refuges for the State Game Commission of Oregon, made a similar recommendation.

In 1916 E. Lester Jones, Director of the United States Coast and Geodetic Survey, made a trip into eastern Oregon, where he observed the antelope in the vicinity of Desert Lake, Jacks Lake, and Guano Lake, the principal herd being in the vicinity of Jacks Lake and containing about 800 animals. In all, he saw more than 1,000 antelope, including a number which had been apparently wantonly killed and then left to lie undisturbed where they fell. On his return from this trip Colonel Jones advocated the establishment of a Federal antelope refuge in Lake County, Oreg., in order to try to prevent the destruction of these herds, and at the National Parks Conference held in Washington, January 4, 1917, he delivered an address on "The future of the antelope," which was printed with a map showing the proposed refuge and distributed as a circular by the National Park Service. His recommendation included the country from Hart Mountain east to the Lake County line and south to include Guano Lake. Colonel Jones warmly advocated the holding of

the antelope conference, and still maintains a keen interest in antelope conservation.

In 1917 and 1918 representatives of the Biological Survey investigated and reported on the antelope situation in that region with a view to the possible establishment of a Federal refuge. In 1919 the secretary of the American Bison Society visited the area in company with a representative of the Biological Survey, and later recommended to his organization that it interest itself in the establishment of the proposed refuge.

Ever since the refuge was first proposed the National Association of Audubon Societies, through its Oregon representative, William L. Finley, has taken an active interest in it; and in 1923, through the efforts of the Biological Survey and the National Association of Audubon Societies, a meeting of stockmen of Lakeview was held, and favored the creation of a Federal wild-life refuge, with the understanding that local stockmen within the area should continue to retain their grazing and other rights. It was as a result of this meeting that resident stock growers attended the antelope conference in Washington, as set forth above.

ESTABLISHMENT OF ANTELOPE REFUGES IN NEVADA

In 1923 Gov. J. G. Scrugham, of Nevada, who had been empowered by the State legislature to create 25 State game refuges, requested the assistance of the Biological Survey in determining suitable locations, particularly those to be made for the protection of antelope. E. R. Sans, supervisor of predatory-animal and rodent-control work of the Biological Survey in the State, consulted with the governor, and as a result two antelope refuges were established—the Washoe State Recreation Ground and Game Refuge, lying mainly in Washoe County, in extreme northwestern Nevada, adjoining Oregon (Pl. V, fig. 1); and the Humboldt State Recreation Ground and Game Refuge, on the northern border of the State, adjacent to Owyhee County, Idaho. Following their establishment, on recommendation of Mr. Sans, who was familiar with the region, enlargements of these refuges were made by the governor to include adjacent districts specially frequented by antelope herds.

At the time of its creation the enlarged Washoe refuge was believed to contain about 2,000 antelope, and the Humboldt refuge about 1,000. The Washoe refuge lies adjacent to that part of southeastern Oregon which for some years has been under consideration as the possible site of a Federal refuge for antelope and sage hens. The Humboldt refuge lies immediately to the south of that part of southwestern Idaho which also has been considered as a possible Federal antelope and sage-hen refuge. The establishment of refuges in adjacent parts of Oregon and Idaho would thus afford protection to the antelope herds passing back and forth across the border in this great tableland region, which is obviously so favorable to the perpetuation of these animals.

Predatory-animal hunters under Mr. Sans's direction had been working for a long time destroying coyotes and other stock- and game-killing animals in the region covered by the Nevada State antelope refuges. Work for the destruction of predatory animals in these

areas will continue and will be a great factor in lessening the losses of young antelope and in building up the herds. In addition, the Biological Survey has made an exception to its general rule and has permitted its hunters to be made deputy State game wardens, so that in carrying out their predatory-animal-control work they will be in position still further to assist in the protection of the antelope herds.

Local stockmen have shown a most friendly spirit toward the establishment of the Washoe and Humboldt refuges and have expressed a desire to assist in the protection of the antelope within these areas.

The Washoe refuge contains about 3,888 square miles, and its boundaries are about 312 miles in extent. The Humboldt refuge covers an area of 1,836 square miles, with a distance of 168 miles about its borders. At the request of the governor, the Biological Survey is taking charge of marking the boundaries of both refuges. This is rendered possible through a generous contribution of funds from the Permanent Wild Life Protection Fund, through W. T. Hornaday. Metal signs bearing the following legend are being placed on posts at suitable intervals around the borders of the Washoe refuge, and similar signs about the Humboldt refuge:

NEVADA GAME REFUGE NO. 9

FOR THE PRESERVATION OF ANTELOPE AND OTHER GAME

HUNTING GAME ANIMALS OR BIRDS ON THIS REFUGE IS PROHIBITED UNDER PENALTIES PROVIDED BY LAW

All persons are asked to assist in the protection of antelope, to prevent the extermination of this beautiful animal, found only in North America; also to help protect other game, that the surplus may spread to the surrounding country.

Maintained in cooperation between the State of Nevada; the Bureau of Biological Survey, United States Department of Agriculture; and the Permanent Wild Life Protection Fund of New York.

For further information address

Nevada State Game Commission, Carson City.

J. G. SCRUGHAM, *Governor*.

PROPOSED OWYHEE ANTELOPE AND SAGE-HEN REFUGE, IDAHO

Apparently the first suggestion that a refuge should be made for antelope and sage hens in southwestern Idaho was in a letter dated December 10, 1920, from George Tonkin, United States game warden in that region. In 1921 further information was received from Mr. Tonkin and other representatives of the Biological Survey in that area, and in the same year the American Bison Society became interested in the project, and its secretary, M. S. Garretson, visited the Owyhee region with a representative of the Biological Survey. As a result of his report and recommendations the Bison Society became active in trying to bring about the establishment of this refuge.

The stockmen resident within the limits of the proposed refuge in Owyhee County were practically a unit in its favor on the

understanding that those operating within its limits should retain their existing rights. This, as in the case of the proposed antelope refuge in southeastern Oregon, accorded perfectly with the policy of the Biological Survey and the desires of its cooperators interested in the project.

Many antelope now exist within the limits of the proposed Owyhee refuge, as well as mule deer and other interesting mammals, and many sage hens. It is an ideal arid-region game refuge, offering sage plains varied with groups of low mountains, where considerable numbers of game animals can be maintained without in any way interfering with the grazing interests.

The sympathetic interest shown by the stockmen in this area indicates that if this refuge can be established it will give a fine demonstration of the practicability of maintaining reasonable numbers of game along with the continued use of such an area for stock-growing purposes.

It can not be too often emphasized that it is not the policy of the Biological Survey completely to exclude grazing from game refuges except under very exceptional circumstances. This bureau is convinced that wherever a large area is involved game can be maintained there with stock without interfering with the legitimate utilization of such area for economic purposes.

It is hoped that with a better understanding of the purposes of these refuges, which are mainly to put an end to hunting game within their limits and to bring about a greater protection of game in order that it may be maintained and increase for the benefit of the surrounding region, the neighboring stockmen may come to approve their establishment. It is to be appreciated that refuges of this character should be formed in complete cooperation with the stockmen if they are to be effective.

RESTOCKING EXPERIMENTS, 1924

After a visit to the Grand Canyon National Park in northern Arizona, E. E. Brownell, of San Francisco, suggested in 1922 that the plateau midway down the slope on the south side of the canyon might well be utilized to establish a band of antelope. Following this suggestion, an expert of the Biological Survey examined the ground and found the project to be practicable. W. T. Hornaday, of the Permanent Wild Life Protection Fund, also visited the Grand Canyon and approved the establishment of an antelope herd there. The outcome was that Doctor Brownell and Doctor Hornaday each contributed a very considerable sum to a fund to cooperate with the Biological Survey to carry out the project.

At first it was planned to purchase the young antelope for restocking purposes from Alberta, but later the Governor of Nevada, in recognition of the cooperation of the Biological Survey in the establishment of the State antelope refuges in the northern part of the State, very generously granted a permit for the bureau to capture 40 antelope fawns on the Washoe State Game Refuge. Fortunately O. C. Wood, one of the predatory-animal hunters of the Biological Survey, owned a ranch in the midst of the area occupied by the great antelope herds of that region, which was an ideal place



FIG. 1.—ANTELOPE FAWNS IN INCLOSURE

B2517M

Photograph taken September 4, 1924, in a wire-fenced inclosure built for captured fawns, adjoining a house in Reno, Nev., where the young antelope were held for one month with complete success

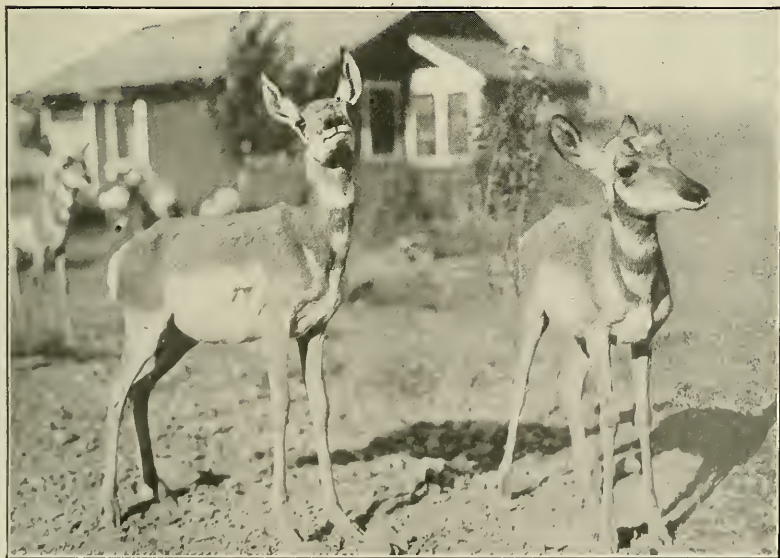


FIG. 2.—YOUNG BUCK AND DOE

B2516M

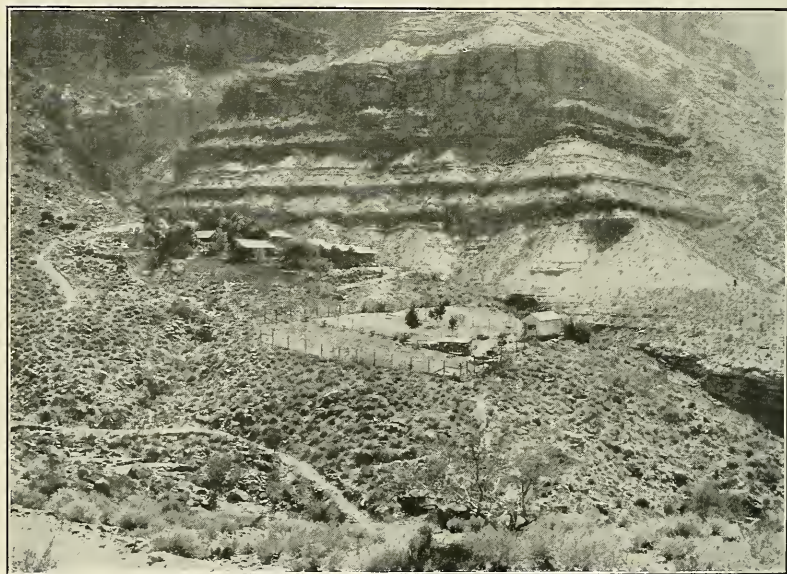
Two members of the band of fawns shown above. The doe, about 15 weeks old, shows no horns as yet (September 4)



B2500M

FIG. 1.—VIEW ON WASHOE GAME REFUGE, NEV.

Photograph taken in the spring of 1924 on the antelope plain in northwestern Nevada. Typical antelope range, the vegetation consisting of sagebrush, with some low grasses and herbs



B2729M

FIG. 2.—HOME OF ANTELOPE IN GRAND CANYON, ARIZ.

Hermit Creek Camp, where 11 young antelope were placed by the Biological Survey in September, 1924. Here they were fed at first by the National Park Service and are proving a great attraction to tourist visitors

to concentrate and care for the young animals when captured and to raise them on the bottle.

This new plan of operations was submitted to the donors of the fund and heartily approved. Its practical execution was placed in the hands of E. R. Sans of the Biological Survey.

Forty newly born fawns were captured in the spring of 1924 by Mr. Sans, and all but a small number were safely reared during the summer and distributed in fall, as detailed below.

The outcome of this experiment has been the placing of 12 antelope in Hermit Basin, in the Grand Canyon National Park, Ariz., where it is hoped they may thrive and increase so as to give pleasure to many thousands of visitors during the coming years. (Pl. V, fig. 2.) Ten of the young antelope were placed on the Niobrara reservation, near Valentine, Nebr., 9 on the National Bison Range, in western Montana, for the purpose of attempting to build up herds of these animals on both of these Federal game refuges, and 2 in the city park at Reno, Nev.

It is obvious that, following Mr. Sans's methods, the capture of young antelope would be perfectly simple in southeastern Oregon, in various parts of Wyoming, and in other districts where considerable numbers of these animals still exist, especially in areas like the Greybull River section of Wyoming, where they have increased until they are looked upon with disfavor by many of the resident farmers.

To perpetuate antelope under fence, even in game refuges covering large areas, experience has shown that very great precautions must be taken first to destroy predatory animals, as bobcats and coyotes. Antelope within such areas appear to lose their freedom of movement and become extraordinarily helpless. This is particularly the case during heavy snowstorms, when they remain within more or less definite areas, in which predatory animals capture them with surprising ease.

The antelope herds in the Wind Cave Game Preserve in South Dakota and on the National Bison Range in Montana, the latter area consisting of more than 18,000 acres under fence, were brought up to a total of about 100 animals. Predatory-animal hunters had been detailed repeatedly by the Biological Survey to kill coyotes and bobcats in and about these refuges until the number of animals thus destroyed amounted to several hundred. Notwithstanding this, however, during severe winter storms in two seasons the band of 64 antelope on the Bison Range was completely destroyed by wandering predatory animals, which were able to drive them into snow drifts and kill them without difficulty. More than half the herd on the Wind Cave refuge also was killed, partly by coyotes and partly by bobcats.

Evidence as to the danger from the bobcats was made plain when the Biological Survey warden, riding through the open pine forest of the Wind Cave refuge during a snowstorm, found and followed the fresh trail of a solitary old buck antelope. He soon came upon the tracks of a bobcat which had taken up the trail also. A short distance beyond he found the antelope, just killed and still warm. It was a full-grown buck in good condition and apparently had been easily killed by the bobcat, which had leaped upon its back.

The difficulties which have attended the establishment of a band of antelope on the Wichita fenced game preserve are detailed elsewhere in this bulletin.

With the reintroduction of antelope on the Bison Range from the Nevada fawns, the placing of a small band on the Niobrara Reservation, and the additions to the band still existing on the Wind Cave Refuge by the Biological Survey, and those on the Wichita Game Refuge by the Forest Service, and in the Grand Canyon and in the Yellowstone National Parks by the National Park Service, the Federal Government is now attempting to build up herds of pronghorns in six widely scattered localities within the limits of their former range.

METHODS OF CAPTURING AND TRANSPLANTING ANTELOPE

The following statement by E. R. Sans, supervisor of predatory-animal-control work of the Biological Survey in Nevada, who successfully directed the capture and rearing of the 40 young antelope in northwestern Nevada during the spring of 1924, contains so interesting and straightforward an account of the methods followed that it should enable anyone to repeat the operations successfully wherever any considerable number of antelope occur:

In the northern part of Washoe County, where we captured the young antelope fawns, I estimate that there were from 1,000 to 2,000 antelope ranging during the year except in the winter months. During the fall of 1923 they began leaving this range the latter part of November and began returning the first of March, 1924. During December, January, and February they ranged in the High Rock Canyon country, about 40 or 50 miles south of their summer range.

In a letter received early in May, 1925, Mr. Sans sums up his latest impressions concerning the antelope of this section as follows: The bunch at Last Chance, where we took the fawns last year, generally leave the plateau country about the last of November and work both ways, north and south, part of them going down into Guano Valley along the Oregon border and, I believe, crossing into Oregon, and the others south down the High Rock close to the Black Rock Desert. The large bunch that ranges during the summer east of Guano Valley, in the high plateau country drift the same way, some going into Guano Valley and others into Virgin Valley and down toward the Black Rock Desert.

On April 18, 1924, I visited the summer range, and while riding on horseback over one of our predatory-animal trap lines I saw antelope everywhere I looked in bunches of 3 to 9. The does were becoming heavy with fawns, and I looked for them to start dropping them about the first of May. In order to be ready when the first fawns were dropped, I selected three men to start working on May 1. They were to establish camp at the Last Chance Ranch, owned by the Hapgood brothers, located at the head of the antelope range. O. C. Wood, Leo Wellmunter, and True Hapgood, one of the owners of the ranch, made up our crew. They were to ride the range each day, watching the female antelope to learn when the first young were dropped. They were beginning to become discouraged when, on May 17, they discovered the first new-born fawn. On May 19 I arrived at the Hapgood Ranch accompanied

by Smith Riley, in charge of reservations, Bureau of Biological Survey, and found the boys had 7 antelope fawns in one of the rooms of the house. They were awkward-looking things, all legs and ears.

LOCATING AND CAPTURING FAWNS

Our method of capturing the fawns was to ride out on the range early in the morning, keeping ourselves from view and using powerful field glasses in looking at the scattered antelope until we discovered a female that showed she had dropped her fawns. Then it was a matter of keeping her in view until she went to feed her young, which she had hidden out, generally one in a place, possibly 75 to 100 yards apart [Pl. II, fig. 1.] Along about 8.30 to 10 in the morning she would go to water, then gradually feed back toward her fawns, never looking toward them but feeding as unconcernedly as if she were merely getting her morning's breakfast. Suddenly you would see a little speck raise up and the mother squat so that it could nurse. She would allow it to suckle a few minutes and then go on, the fawn following her until she picked up the twin. Then the same process would be repeated. The mother then would feed about possibly 20 minutes or a half hour, accompanied by the fawns, when one of them would drop down and she would lead the other about 75 to 100 yards and leave it also lying down. One particular doe that I was watching stopped suddenly and one of the fawns started running at right angles from the direction the mother was going, and when about 50 yards away dropped down as if it had been shot. The mother fed gradually on, leaving it there.

After the mother had left the immediate neighborhood of the hidden fawns we took particular care to sight up with objects so we could ride to the fawns. They were generally lying in the sun on the lava rocks with no shade to protect them, their heads stretched out on the ground, ears lying flat on their heads, and very difficult to see. They would allow us to walk up almost beside them before they would make a move. Then they would jump up and develop a wonderful burst of speed for about 30 or 40 yards, when their legs would begin to tangle up and they would fall down. I was successful in capturing two of them one morning, and was in doubt as to which of us was the most exhausted by the race when we both fell at the end.

As soon as the young were captured they were placed in a grain sack with a hole cut in the side about 4 inches from the bottom, just large enough for the head to be put out. [See Pl. II, fig. 2.] One was hung on each side of the saddle horse and thus carried to camp, where they were kept until a sufficient number were caught to warrant a trip to the permanent inclosure at the ranch. (Pl. III, fig. 1.)

The mothers are very suspicious and will not go near the fawns if they can see or scent a person; therefore much caution must be exercised in selecting a hiding place when watching to locate the young.

FEEDING ON THE BOTTLE

The next most important thing is food for the young. We found that to begin with, the best ration was rich cow's milk, about two-thirds of a pint at a feeding, heated to a little more than the body temperature and fed from a bottle through a nipple known as a lamb's nipple. Great care must be exercised not to overfeed. As the fawns all look alike, when you get a lot of them together it is necessary as soon as each one is fed to separate it from the others. Overfeeding will probably cause scours, which are difficult to handle.

In the raising of our 40 kids we had only one that developed a real case of scours. While we brought it through by a liberal dose of lime water and

castor oil, it never did so well as those that had not had it. We also found that whenever one of them looked a little dumpy, a tablespoonful of castor oil invariably brought it around within 24 hours. The warm milk was fed three times a day, 6 o'clock in the morning, noon, and 6 o'clock in the evening. (See Pl. III, fig. 2.)

GRAIN AND GREEN FEED

When the fawns were six weeks old we began to feed them a little wheat (bran and middlings) and when they were two months old quite a number were eating it. Then we substituted steamed rolled oats, which they ate readily at the same time that they were also eating considerable green feed from the meadow. When they were about 2½ months old the green feed dried up on account of the extremely dry season, and the fawns began to fall off in flesh, but ate about twice as much grain as they did when the green feed was plentiful.

When they were 3 months old we moved them to Reno, so as to be able to get green feed, as it would have been hard on them to wean them from their milk without it. They were very fond of green lawn cuttings of blue grass and white clover, and we cut it from the lawn three and four times a day, feeding it to them fresh and keeping an ample supply of rolled oats where they could go to it at all times. They did not appear to miss the milk, which was discontinued on August 25, with the exception of five or six weaklings and cripples which were fed milk until the 5th or 6th of September. Even though we had discontinued the milk, the kids began to fatten up and grow fast upon the green-feed and rolled-oats diet.

We shipped some of them on the 9th of September, when their average weight was 42 pounds, at 3½ months of age. They ranged in weight from about 35 up to 50 pounds each.

We purchased a bale of first-cutting, well-matured alfalfa hay, keeping a supply in the inclosure from the time they were 3 months old, and they would feed a little at a time on this, and no doubt if they did not have an ample supply of green feed they would have taken to it very readily. For a winter diet I believe well-cured meadow hay and rolled oats would be the best. In feeding alfalfa hay care should be exercised not to get unmaturing second or third cuttings, as there is danger of its causing bloating. Mr. Green, of the California Fish and Game Commission, told me that they had lost several deer and elk from allowing them to feed on green alfalfa in the field.

TRANSFER TO TEMPORARY INCLOSURE

When a sufficient number of fawns were caught to make a load they were placed in an automobile and taken to the Wood ranch at Diessner, Nev., where we had built a wire-fenced inclosure containing 5 acres of meadowland. The distance by road was about 55 miles, but going by saddle horse it was only 12 miles. It was much easier on the fawns to go in a car, even a much greater distance, than it would have been on pack horses for a shorter distance.

In building temporary inclosures to hold antelope fawns until they are old enough to transfer to their permanent homes (Pl. IV) much care should be taken to have all posts on the outside of the wire netting and all braces so placed that there will be no projections inside for the fawns to run against. The feeding corral should be small and made of dressed lumber with no cracks, or if net wire is used it should be lined inside with sacking to keep the animals from getting hurt when they become frightened.

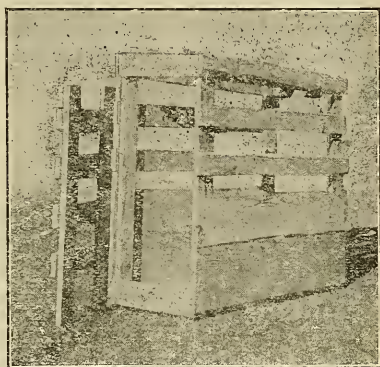
CARE TO PREVENT FRIGHTENING

Antelope fawns are very panicky when something unusual occurs. The attendants must move slowly, talking to them at all times; quick movements frighten them. Upon entering the place where they are confined, if one will talk to them and be careful to move slowly, in a few minutes they will settle down and allow him to work among them without signs of fear. Even after they are 2 or 3 months old it is necessary to use much caution when going among them, but I noticed that the fawns usually come running to a man when they become frightened, apparently for protection. When suddenly frightened, however, they may rush at full speed into a fence without apparently seeing it. With a single exception every fawn we lost was injured or killed outright from being frightened. Two of them broke their necks by hitting the wire fence on a slant, running their noses into the mesh.

Fawns apparently have a hereditary fear of cats and dogs, and I believe cats scare them worse than the dogs. I have been wondering if the bobcat family isn't one of their worst enemies on the range.

We found out when we crated the animals at Diessner that one must be very careful, for after a few were caught the others became frightened. At first we caught all the gentle ones, leaving the wild ones until the last. When we came to the last two, which were the wildest of all, one of them made a frantic jump at the wire fence, striking it on the slant and breaking its neck.

When we recrated them at Reno I purchased lumber and made a corral about 8 by 20 feet with a lumber chute narrowing to about 4 feet wide at one end. Putting all the fawns into this small inclosure, we picked the wildest one first and by catching the four or five that did not come to us readily when they were out in the big inclosure we had no trouble whatever. The old gentle stand-bys did not become frightened, and within a few minutes we had the total number for shipment crated.



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FIG. 2.—Specially constructed crate for shipping 4-months-old antelope. Made of five-eighths-inch material and requiring 20½ feet of common lumber, the inside measurements being 38½ inches long, 33 inches high, and 13 inches wide. Weight, 35 pounds. Cost of making crate and lining with burlap, including labor and materials, \$2.40

SHIPPING CRATES

Crates should not be built too large. (Fig. 2.) A crate for an antelope averaging 50 pounds in weight should be about 38½ inches long, 13 inches wide, and 33 inches high, inside measurements, using select dressed lumber, about one-half or five-eighths of an inch thick by 3 inches wide. The bottom and sides up for about 12 or 14 inches should be solid, and then 3-inch strips placed 3 inches apart on the sides and ends to allow good ventilation. The two strips above the solid bottom board should be wrapped with burlap so as to make a padded crate. It is well to take a small joining plane and run over the edges of the boards so that there will be no sharp edges to cut.

The main thing in making a crate is to have it so narrow that the animal can not change ends in it. Antelope should be put in the crate backward with head toward the door. The door should be made so that it will slip in a slot

at the bottom and then can be tied at the top with stout cord. Room for a water can and space for grain should be allowed in the front. Coarse straw at least 3 inches deep should be placed inside for a bed while in transit.

The express company charges one and one-half times the first-class rate on live animals, but does not include in the weight the feed necessary while en route. Water and feed should not be placed in the crates, therefore, until after they are weighed and billed out.

TRANSPORTING ANTELOPE IN CRATES

Animals should be crated singly, for where two or more are together they will cut each other with their sharp hoofs. When one lies down the other will invariably step on it. In the 240 miles that we transported the fawns from Diessner to Reno by automobile truck they were crated singly and endured the trip in fine shape. We left Diessner at 2 o'clock in the afternoon and, driving all night, arrived in Reno at 8.15 in the morning, thus making the trip during the coolest period of the day.

We have demonstrated beyond a doubt that young antelope can be successfully taken from their natural range and raised if care is exercised in handling them.

Great care must be taken to keep all milk containers, bottles, and nipples perfectly clean, and I would suggest that if any more antelope are taken in this district they be transferred direct to Reno as soon as the required number is captured, where unlimited supplies of milk can be obtained and also all other necessary food. It is not necessary to have such a large inclosure as we made at the Wood ranch, and I believe the antelope become gentle more readily where they see people constantly passing.

RESULTS OF A CENSUS OF EXISTING ANTELOPE

For many years the Biological Survey has been engaged in determining the former and present range of the pronghorn. In 1922 it became evident that the time had arrived for active measures leading to their conservation if their extermination was to be avoided. In order to form a basis on which intelligent conservation measures might be built a definite census of the surviving pronghorns was undertaken. This was continued from 1922 well into 1924 through field men of the Biological Survey, with the active and friendly cooperation of State game officials, State game protective associations, and individuals, not only in the United States but in Canada and Mexico, involving a great deal of correspondence.

In taking the census of the antelope in the United States the survey has been fortunate in having a field organization for the control of predatory animals and of harmful rodents in each of the 16 States where the pronghorn still occurs. Their operations in these services are of State-wide character and are conducted in cooperation with the State extension services, State departments of agriculture, and other organizations, as well as stockmen and farmers. Their work puts them in touch with county agents, sheriffs, and other officials, hunters, and men generally familiar with the State. The State game officials were particularly helpful, and the field force of the United States Forest Service also added many facts. Without the contributions from these varied sources this report could not have been prepared. Each contributor is entitled to feel that he has

definitely assisted in a work which may be the basis for definite action in various States to insure the perpetuation of the pronghorn.

In taking this census determined efforts were made to locate as completely as possible each surviving band and, wherever possible, to have an actual count of the animals in it.

Almost throughout its range the pronghorn is decreasing. Each succeeding year some of the smaller herds marked on the accompanying maps are certain to disappear, and only in the most favorable areas, where they are carefully protected, is there hope for the long survival of these interesting animals. In perpetuating herds of antelope in the different States one of the principal factors will be the interest taken in them by ranchmen, local sportsmen, and other residents. Antelope are on the verge of final extermination in Kansas, where in the early days they were familiar sights from the windows of passing trains.

There is little hope for the preservation of the large number of small bands containing from three to a dozen or more pronghorns. Under present conditions, when a band is reduced to a very small number, its continued existence is practically impossible unless it has the benefit of exceedingly careful guardianship.

The decrease of antelope is governed by a number of conditions, among which may be mentioned the inroads of predatory animals, illegal shooting, and the increased occupation of their territory for economic uses and the disturbance brought about by it. There may be improvement as to the first two of these factors, but the last is one which is necessarily beyond control. This means that eventually the surviving antelope will be limited to bands located in some of the more desert and least occupied parts of their former range, such as in northwestern Nevada, or to large, fenced game refuges. There are areas in many of the Western States which are suitable for the maintenance of bands of antelope on the open range if public sentiment will interest itself in them.

The largest herds of antelope in any restricted area appear to be located on the great plains which cover northwestern Nevada and adjacent parts of Oregon and southwestern Idaho. In this isolated, sparsely populated region may still be found the nearest approach to original conditions of any part of the antelope range in the United States to-day.

There is no intention to claim anything like complete accuracy in all the specific localities and numbers of antelope set forth. From the very nature of the case that is obviously impossible. Furthermore, with the decrease of antelope some of the small bands here listed may have already disappeared. Also occasional bands here and there may have been missed, and the numbers estimated for many may be erroneous—either too great or too small. It is earnestly desired that all who are in position to give constructive criticism will send in the information which they possess in order that corrections and additions may be made on the records.

Table 1, on page 3, summarizes the number of bands of antelope and the total number of animals in each within the various geographic areas. Following is a detailed statement showing the location and distribution of the bands in each of the areas listed.

ARIZONA

In 1923 antelope in Arizona were restricted to bands occurring in 18 areas and totaled about 650 animals. A more intensive investigation might slightly increase this number. Formerly they existed in great numbers in this State, where the range and climatic conditions were peculiarly favorable to them. In the eastern part of the State from 1884 to 1889 they were very numerous both on the grassy plains and in the parklike openings among the scattered cedar, juniper, and pinyon forests covering vast areas of that great plateau region. In summer they ranged also among the yellow-pine forests on the Mogollon Plateau, but the heavy snows on these higher elevations forced them into the lower country in winter. As elsewhere at that period, there was no appreciation among sportsmen and the general public of the need of any restraint in killing game, and both antelope and other kinds of big game were killed freely throughout the year. With the increasing occupation of the ranges the antelope have steadily decreased and now are extinct over great areas where they once abounded.

The information concerning the number of antelope now in Arizona has come mainly from M. E. Musgrave, in charge of the predatory-animal work, and D. A. Gilchrist, of the rodent-control work, both of the Biological Survey. Their personal familiarity with all parts of the State has enabled them to make an excellent preliminary survey of the situation. On December 15, 1923, Mr. Musgrave wrote:

"We have collected fairly accurate data on the antelope of this State and I have found that the number of young this year ranges from 10 to 25 per cent of the total number of animals a year or more old. The heaviest percentages of young are on the ranges in the vicinity of Valentine, north of Seligman. It is believed that there were 25 per cent of young born in the Sitgreaves National Forest and only about 10 per cent on the Prescott National Forest and adjacent to it. The small band located in the San Fernando Valley, south of Tucson, had an increase of about 20 per cent. The total increase for the State for the present year should be about 15 per cent.

"The antelope that live on the Anderson Mesa have been materially reduced in number. Last year they numbered more than 100 head, but now only 25 survivors are reported. I am inclined to believe that the antelope in Arizona are increasing regardless of the rapid depletion of the herds on the Anderson Mesa, south of Flagstaff, and along the Verde rim. Antelope appear to be increasing on cattle ranges in the State and decreasing on sheep ranges."

The distribution of antelope in Arizona is approximately as follows (fig. 3):^a

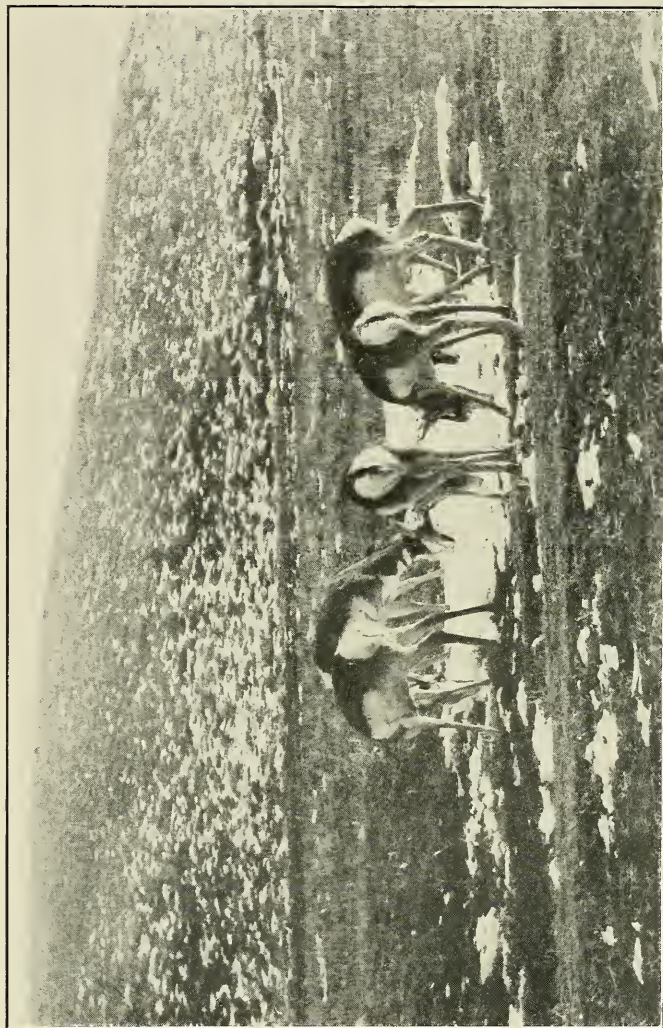
1. About 12 antelope are reported as ranging in Antelope Valley, between Hurricane Ledge and Kanab Creek, north of the Grand Canyon, in Mohave County.

2. In 1923, according to residents of Grand Canyon and railroad men employed on trains between Williams and Grand Canyon station, in Coconino County, about a dozen antelope still occurred in the vicinity of Anita, or between Anita and Cataract Canyon. They are seen occasionally from the trains.

3. About 50 in small scattered bands occur in open parks in the yellow-pine forest north of Flagstaff, in Coconino County.

4. Supervisor Miller, of the Coconino National Forest, reported in 1923 that the antelope ranging on Anderson Mesa, southeast of Flagstaff, in Coconino County, in 1913 numbered about 200, but that in 1922 they had become reduced to about 100, and in 1923 to about 25. This decrease indicates the danger of extermination confronting this herd.

^aThe paragraph numbers in this and other States and Provinces correspond to the numbered areas shown on the respective distribution maps, the number of the area being the figure outside the circle, the number of antelope in each area being expressed by the figure within the circle.



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ANTELOPE IN WIND CAVE REFUGE, S. DAK.

As shown in the illustration, antelope sometimes eat snow and then are able to get along in winter without water

5. Formerly many antelope ranged on the sagebrush plains southwest of Winslow, in Navajo and Coconino Counties, but in 1923 these had become reduced to 10, located in Coconino County.

6. About 50 are reported on the open range near Heber, in Navajo County.

7. About 50 are reported as ranging along the Verde rim, northeast of Camp Verde, Yavapai County.

8. About 40 are ranging in Cedar Glade, south of Ashfork, in Yavapai County.

9. In 1922 several bands, aggregating 100 or more, were reported to be ranging on the Baca Grant, 50 miles south of Seligman, in Yavapai County.

10. A band of about 50 is reported as ranging in the open country near Seligman, in Yavapai and Coconino Counties.

11. In 1922 about 80 were reported to have been on the Carrow cattle range, southwest of Nelson, in Mohave County. These probably also range into Yavapai County. The Carrow brothers give strict protection to the antelope on their range, where they have increased within the last 10 years from about 15 animals to the present number.

12. A band of 25 is reported as occupying the open range southeast of Springerville, in Apache County. From 1884 to 1890 bands aggregating 500 to 600 antelope occupied this territory.

13. In 1923 bands aggregating about 75 antelope were reported to have been ranging in Yuma County, near the international boundary. Seven head were reported in 1924 between the Mohawk and the Cabeza Prieta ranges.

14. In 1923 Papago Indians reported that a few antelope were still ranging in Santa Rosa Valley, in Pima County, but no definite number was given.

15. In 1923 about 30 antelope were reported occurring on the mesa west of Oracle and along the road to Florence, about 35 miles northwest of Tucson, in Pinal and Pima Counties.

16. According to residents of Arivaca, about 20 antelope occur in the upper end of Altar Valley, not far from San Fernando Valley, in Pima County. Near a small lake near the middle of the valley in 1923 a number of young were noticed with this band, indicating that it may be slowly increasing.

17. In 1923 a band of about 12 was ranging on the plains near the north end of a small mountain range locally known as the Sierrita, southwest of Tucson, in Pima County.

18. In 1923 about 10 antelope were ranging on the plains near Benson, in Cochise County.

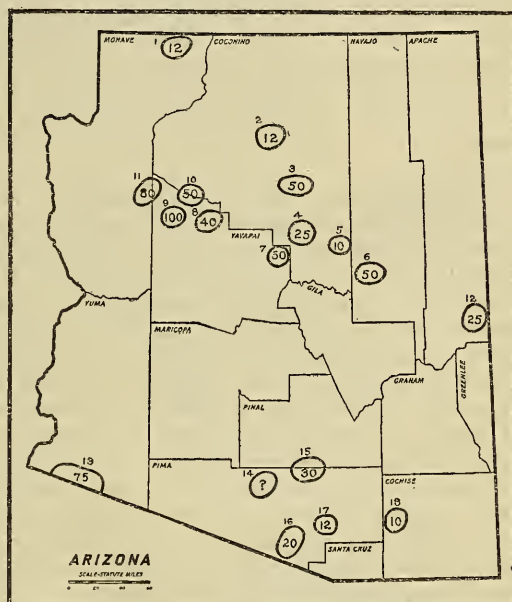


FIG. 3.—Distribution of antelope in Arizona; estimated at 651, in 18 areas

CALIFORNIA

During the middle of the last century when the gold rush took place, antelope were generally distributed and very abundant on the plains of California, especially in the San Joaquin Valley and over the Mohave Desert region, ranging thence south to the Mexican border; also on the arid plains in the northeastern part of the State. In 1923 they had been reduced to small bands in six widely separated areas, containing a total of about 1,057 animals.

Although the intensive occupation of California is making nearly all parts of the State impossible for the presence of antelope in a state of freedom, there are a few areas within which herds might be perpetuated, especially in the northeast. Fortunately, the State fish and game commission is taking an active interest in the matter, as is also the committee for the conservation of wild life of the California Academy of Sciences.

At the Washington Antelope Conference F. M. Newbert, president of the board of fish and game commissioners, stated that for a long time the game commission has taken an active part in trying to safeguard the surviving antelope. At one time the Mount Dome herd (No. 1 on the map) had dwindled to 11 animals. Through the interest of the commission in safeguarding these animals by its warden service the number has been increased until now there are about 118. Mr. Newbert expressed a desire to cooperate with the Biological Survey and also with the authorities of the States of Nevada and Oregon in any practical way to perpetuate and if possible increase the antelope herds. It will be difficult to perpetuate the four small herds in the southern part of the State, but in the northeast there is greater promise of success.

A correspondent who visited northeastern California in the fall of 1922 stated that three-fourths of the dry farms have been deserted in that region, which naturally tends to restore favorable conditions for the antelope. The committee for the conservation of wild life of the California Academy of Sciences has raised funds for feeding the Mount Dome antelope in severe winters and has joined with the State game commission in having game wardens protect them from poachers. It is planned to try to have an antelope refuge established for their benefit. M. Hall McAllister, chairman of that committee, wrote on July 16, 1924: "By reason of the remarkably open winter of 1923-24 the Mount Dome herd remained scattered and did not band up as they usually have done: therefore, no tally was possible on them as has been usual. Also by reason of the small rainfall and few heavy storms in California the Lassen herds [No. 2 on the map] have migrated across the line into Nevada, and in July, 1924, not over a dozen were sighted on their old grounds in Lassen County, although some 500 are reported ranging in the neighboring part of northwestern Nevada."

No doubt the shifting of the Lassen County herds to the adjacent part of Nevada was caused by shortage of feed in the California area, and these animals may be expected to return to Lassen County as soon as adequate rainfall again restores the proper forage conditions. For this reason this herd is being credited to California, which appears to be their natural home. Fortunately, the area they have gone to in Nevada lies within the antelope refuge established in 1923 by the governor, thus affording them protection.

In California, as elsewhere, coyotes and other wild animals prey upon the diminishing herds of antelope, as upon other wild life. Wherever it is practicable the Biological Survey is having its field leaders give special attention to the destruction of predatory animals endangering the surviving herds of antelope and other large game. Hunter Fay Clark, working cooperatively for the Biological Survey and the California Department of Agriculture in the Mount Dome district, has been successful in destroying coyotes which have been preying on the antelope and deer of this district. The inroads of these pests undoubtedly account for the slow increase of this herd. In a single month, in the range of these antelope, Mr. Clark killed 35 coyotes. The result of his work will undoubtedly become apparent in an increase of the game animals of that district, as has been the case following similar work in other parts of the West.

The detailed information concerning the distribution and number of antelope now in California has been supplied mainly by M. Hall McAllister, of the California Academy of Sciences; George Neale, executive officer of the California Fish and Game Commission; and F. E. Garlough, of the rodent-control section of the Biological Survey.

The distribution of antelope in California is approximately as follows (fig. 4) :

1. John O. Miller reported on February 28, 1923, that the Mount Dome herd contained about 118 antelope. They range on the plains in the southern end of Lower Klamath Lake, near Mount Dome, in Siskiyou County, probably the most favorable area in California for perpetuating antelope under natural conditions. For some years the herd has had the attention of the State fish and game commission and other conservationists, as set forth above, and with the destruction of predatory animals in that district should increase in numbers.

2. The Lassen County antelope, scattered in numerous small bands on Madeline Plains, in Dixie Valley, Secret Valley, and other points, range eastward into the Smoke Creek Desert of Nevada. These were counted by W. J. Lee, who reported on September 29, 1923, that they aggregated 864 animals. Since then it has been reported that most of these animals have crossed the State boundary into the adjacent part of Nevada, as a result of failing forage due to the excessively dry season of 1924. They will undoubtedly return with the restoration of more favorable conditions.

3. In 1922 two small bands, totaling 29 animals, were reported as ranging between Mendota and Panoche Creek, on the west side of the San Joaquin Valley, in Fresno County.

4. A band of about 30 was located in 1922 between Granite Wells and Randsburg, on the Mohave Desert, in San Bernardino County.

5. In 1922 a band of 11 lived in Antelope Valley on the Kern-Los Angeles refuge, ranging over adjacent parts of Kern and Los Angeles Counties. In April, 1924, 13 were reported as having been seen between Willow Springs and Liebre Ranch, on the west side of the valley in Kern County.

6. A band of 5 was reported in 1922 ranging in the desert north of the State highway between Campo and Imperial, in Imperial and San Diego Counties. These animals probably range back and forth across the Mexican border.



FIG. 4.—Distribution of antelope in California, estimated at 1,057, in six areas

COLORADO

The plains of Colorado formerly abounded in antelope. It is surprising that with the long-continued occupation of this State by farmers and stockmen bands of antelope still survived up to October, 1923, in 28 localities, aggregating approximately 1,233 animals. This indicates an interest in or at

least a tolerance of these animals, which might well be converted into such an active spirit of protection as would perpetuate a number of herds in suitable localities.

The very excellent census of antelope in Colorado here presented is due largely to the persistent efforts of John H. Hatton, secretary-treasurer of the Colorado Game and Fish Protective Association, and to the work of Stanley P. Young and Joseph Keyes, in charge of the predatory-animal and rodent-control work of the Biological Survey in the State. Mr. Hatton wrote that the active interest of the Colorado Game and Fish Protective Association in the conservation of antelope will undoubtedly be very helpful in bringing about their perpetuation.

Early in 1923 the legislature of Colorado established the Colorado Antelope Refuge in northern Larimer County, on the Wyoming line, which covers the territory occupied by a band of about 75 animals. The fall of the same year Mr. Hatton wrote concerning the plans of the Colorado Game and Fish Protective Association:

"We plan during the next legislature to have presented some areas in the eastern part of the State which would be suitable for antelope refuges. We first became interested in this subject as an organization a couple of years ago, and it seemed that the first logical step would be to get a census of the species, which, as you know, has already been done. I plan also a little later to address a letter to the local newspapers where antelope are found, giving a little account of them and making appeals for their protection."

The general results of inquiries concerning antelope in Colorado indicate that these animals are steadily decreasing, especially on the eastern plains. There has been some discussion of the possibility of rounding up the survivors in this region and placing them under fence in northeastern Larimer County in the antelope refuge recently established.

Antelope once abounded in North Park, but the county assessor of Jackson County, in a letter dated October 31, 1923, stated that none remain and that the last band, containing 21, was killed many years ago by hunters from Fort Collins. About 35 years ago in that district a hunter used a telescope rifle for killing antelope, for which he was paid \$1 each. Wagons were sent out to pick up the animals, which were shipped to Denver for sale.

The results of the census of antelope in Colorado indicate that there is still time to build up fine herds of these beautiful animals in parts of the State where they will not become obnoxious to the farmers. A careful study of the situation should be made for the purpose of locating satisfactory areas where definite efforts can be made to have State refuges established, and in addition of enlisting the cooperation of men having large fenced pastures to maintain small antelope herds as a matter of interest. Apparently one of the vital needs in Colorado, as in many other States, is to insure a better enforcement of the law against those who wantonly kill antelope. A large proportion of these animals now being killed are, no doubt, shot merely for passing amusement.

The distribution of antelope in Colorado is approximately as follows (fig. 5):

1. Not less than 150 antelope range between Vermilion Creek and the head of Sand Wash in northwestern Moffat County. The majority of the people in that district seriously object to these animals being killed, although it is stated that occasionally a resident shoots one for his own use.

2. In Middle Park, northwestern Grand County, a small band of 7 still exists. This was formerly a favorite range for antelope, but they have been rapidly decreasing there and will probably be completely exterminated in the not distant future.

3. A band of about 75 is located in northeastern Larimer County, on the Colorado State Antelope Refuge, mentioned above. These antelope, no doubt, range across the boundary into southern Wyoming, and are said to be holding their own and possibly increasing. Some of the people in this district favor the protection of the antelope, while others do not and are reported to look upon them as a nuisance.

4. About 33 antelope are reported from north-central Morgan County, where they are said to be decreasing.

5. In Logan County about 150 survive. There is some complaint here of their destroying crops. Although antelope appear to be occasionally shot in this district, the herd appears to be holding its own and with a little better protection would undoubtedly increase. It is obvious that the relation of these antelope to the farming community requires careful study before any definite effort is made to build up the herd.

6. C. F. Parker wrote from Julesburg in October, 1923, that about 55 antelope are located in the northwestern corner of Sedgwick County, where the farmers desire their protection. In winter they come down and feed in the

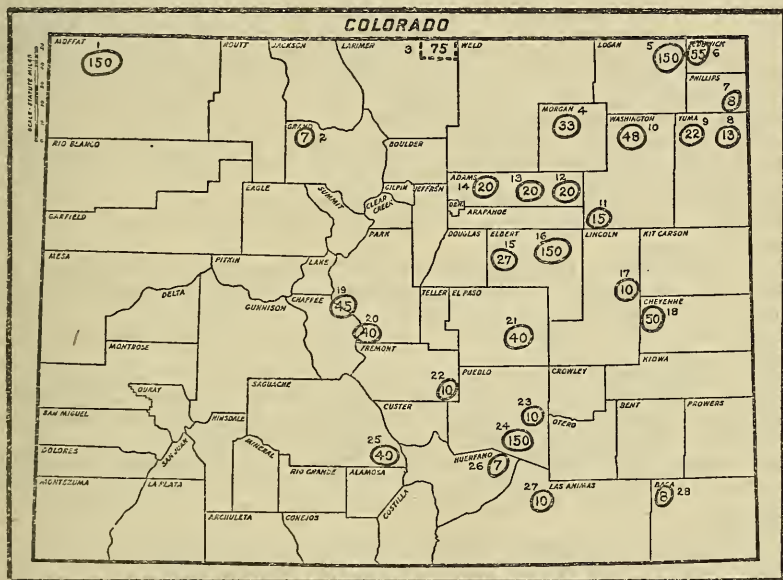


FIG. 5.—Distribution of antelope in Colorado, estimated at 1,233, in 28 areas. Antelope refuge indicated by broken lines

alfalfa fields. They are said to be increasing. Mr. Parker stated that when he fenced an 8,000-acre pasture at his Cottonwood Ranch about 20 years ago 2 does and 1 buck antelope were included. They have steadily increased since that time, and it is generally understood in the neighborhood that anyone caught molesting them will receive the limit of the law. Occasionally in that district antelope are pursued and shot by hunters in automobiles, but the resident farmers are interested in them and desire their protection.

7. A small band of eight has about held its own for several years in southeastern Phillips County. The people in that district are interested in them and favor their increase, which no doubt could be brought about by a little more careful protection.

8. A band of 13 is located in northeastern Yuma County.

9. A band of 22 is reported from northwestern Yuma County.

10. In northern Washington County, the existing herd numbers about 48, and their protection is favored by most of the people in the county, although occasionally one is shot. Suggestions have been made that they be captured and removed to a fenced refuge, but this is not generally favored.

11. A band of about 15 has been reported from southwestern Washington County. It is stated that both this and the band in the northern part of this county are about holding their own. H. R. Rice, assessor of Washington County, wrote under date of October 27, 1923, that about two months previously 2 antelope had been shot north of Plattner and left as they fell, and that 3 were killed in the same neighborhood a year or so before, but that efforts to locate the killers were unavailing. Mr. Rice thinks that the partial protection the antelope receive has a tendency to cause them to lose their fear of man, and this enables poachers to kill them with little difficulty. He thinks that they could best be perpetuated by inclosing them in a pasture from which each year the surplus bucks might be killed by hunters. This idea appeared to appeal to some of the local sportsmen.

12, 13, and 14. Three bands of about 20 each are reported from Adams County. It is stated that there is not much local interest in them and the herds are decreasing.

15 and 16. About 27 antelope are said to remain in the western part of Elbert County and 150 in the northeastern part. Their protection is favored by most of the people living in that district; but it is reported that they are frequently hunted, especially by men in automobiles. Notwithstanding this, the herds are reported to be about holding their own. It has been suggested that an antelope refuge might be established for the larger of these two herds.

17. A band of 10 or more antelope is reported in east-central Lincoln County. There is some not very active sentiment for their protection, and through killing by poachers the herd is decreasing.

18. In northwestern Cheyenne County about 50 antelope still remain. There is said to be little sentiment in favor of their protection, and they are being killed by hunters.

19. About 45 antelope occur about 10 miles north of Buena Vista, on the line between Chaffee and Park Counties. Local sentiment is very favorable to their protection.

20. In southwestern Park and eastern Chaffee Counties is a band of 40. The majority of the residents in this section favor their protection, but the band is decreasing, probably through hunting.

21. In July, 1924, a band of about 40 antelope was reported in east-central El Paso County.

22. In southeastern Fremont County a band of about 10 still survives. Their protection is favored by residents, but occasionally one is killed by hunters.

23 and 24. In July, 1924, a band of 10 was reported in the east-central part of Pueblo County, and one of about 150 in the south-central part.

25. About 40 are reported from near Crestone, in southeastern Sagauche County, on the Luis Maria Baca grant No. 4. They are under fence in this grant and as a result of the protection they are receiving are reported to be increasing.

26. A band of 7 is reported in the extreme eastern part of Huerfano County.

27. A band of 10 ranges in north-central Las Animas County.

28. A band of 8 is reported in the northwestern Baca County.

IDAHO

Bands of antelope are reported in 14 areas in Idaho with an aggregate of approximately 1,500 animals. They are located mainly in the east-central and extreme southwestern parts of the State. Information concerning them has been obtained from R. E. Thomas, State game warden; United States Forest Superintendent Olsen; and L. J. Goldman, leader of the Biological Survey's predatory-animal work in the State.

During the past four years considerable work has been done to bring about the establishment of a Federal antelope and sage-hen refuge, covering the Owyhee desert country in the extreme southwestern part of the State, in Owyhee County. Details concerning this are given elsewhere in this bulletin.

The present distribution of antelope in the State is approximately as follows (fig. 6):

1. A band ranges in Antelope Valley and the Pahsimeroi Mountains in Custer County. Forest Supervisor Olsen states that they inhabit the low open ridges lying at the base of the mountains generally, but occasionally a buck

is seen in the higher elevations, even up to 8,000 feet. Mr. Olsen states that at one time he counted 104 antelope in this band.

2. Forest Supervisor Olsen states that three years ago a band of 12 adult antelope made the Sulphur Creek ranger station in Pahsimeroi Valley, Lemhi County, their headquarters. They became very fond of alfalfa, which grows plentifully there, and have remained there ever since, except that they sometimes go back into the hills a couple of miles or so during the winter season. They have been carefully protected by the forest rangers and have increased until the band now numbers 62.

Forest Examiner S. B. Locke writes that at this time antelope in the Pahsimeroi Valley have become a nuisance at several ranches. At the ranch just about the ranger station 20 to 40 antelope enter the fields during the summer and consume approximately one crop of alfalfa. While the hay is tall they do not cause much damage but feed on it intensively soon after it has been cut. Some of the ranchers keep them away from their fields by the use of dogs and shotguns. Any increase in the numbers here would intensify the losses of the farmers.

3. A band of 9 is located near Goldburg, in Custer County.

4. A band of 25 is reported in Lemhi Valley, in southern Lemhi County.

5. About 25 live on Medicine Lodge Creek, in Clark County.

6. About 60 range on Birch Creek, in western Clark County and adjacent parts of Jefferson and Butte Counties.

7. About 75 are reported as ranging in Little Lost River Valley, in Butte and Custer Counties. Antelope from this area are said to range sometimes far out on the Snake River desert.

8. In July, 1924, a band of 4 was seen on the Snake River desert at Arco, in Butte County.

9. A band of 26 was counted in 1923 in the Copper Basin, near Mackay, in southern Custer County.

10. A band of 7 exists near Chilly, on Big Lost River, in Custer County.

11. About 13 are reported to range about Horse Heaven Pass, at the head of Pahsimeroi Valley, in Custer County. A long-time resident of that section states that a few years ago this herd contained about 100 animals.

12. A band of 25 is reported as ranging on Succor Creek, in Owyhee County.

13. Southwestern Owyhee County is the most important area in Idaho for antelope. Reports state that two separate bands occur, one ranging from the Juniper Mountains in Owyhee County to the Nevada line, and the other occupying the country from the crest of the same mountains westward to the confluence of the Owyhee River and Soldier Creek in Oregon. L. J. Goldman, in charge of the predatory-animal work of the Biological Survey in Idaho, wrote that he had reports from authentic sources of from 600 to 1,000 occupy-

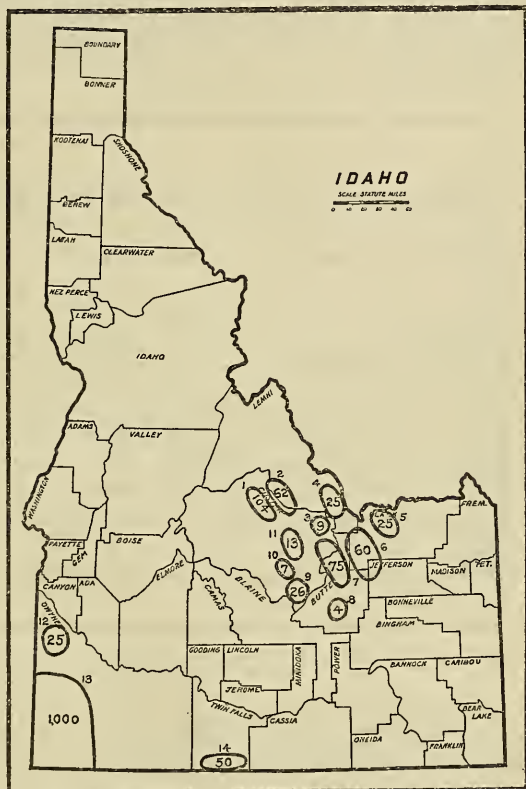


FIG. 6.—Distribution of antelope in Idaho, estimated at 1,485, in 14 areas

ing the extreme southwestern corner of Owyhee County. They range from the Duck Valley Indian Reservation west to the Oregon line and probably into Jordan Valley, Oreg., and from the Nevada State line to a point about 30 miles north. Stragglers and small bands undoubtedly stray beyond these limits. They also cross southward into Nevada. Their main summer range is about the forks of the Owyhee River and the Juniper Basin. E. Grandjean, of the Forest Service, wrote that this band occupies the high plateau drained by the Owyhee River at altitudes varying from 4,500 to 6,000 feet. This area is fairly well watered and overgrown with grasses and sagebrush. In the middle of it are located the low, hilly Juniper Mountains, which are very rocky and cover an area approximately 10 miles wide by 20 miles long. This main plateau, except the wooded part, is used by antelope as spring, fall, and winter range. The animals usually appear there early in April and remain until early in winter, when the snow compels them to leave for their winter range, generally believed to be the low desert plateau lying south of the main Owyhee River.

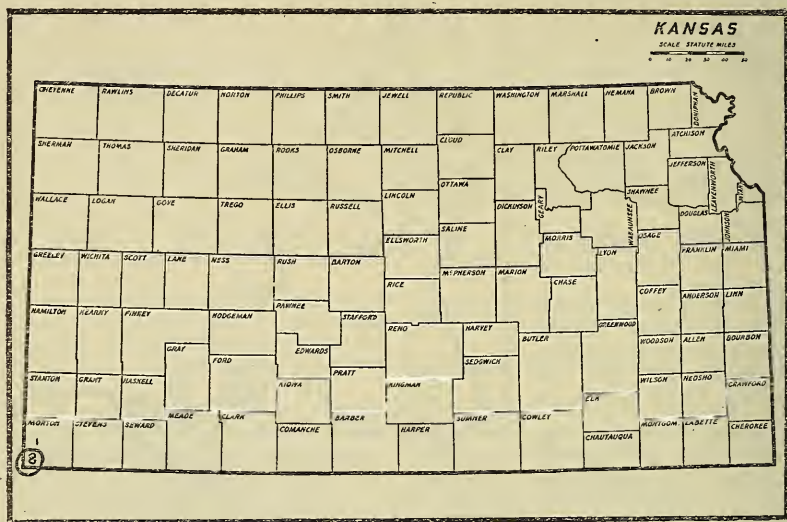


FIG. 7.—The only band of antelope in Kansas occurs in the extreme southwestern corner; estimated to contain 8 animals

14. Scattered bands numbering about 50 are reported to live on Browns Bench, along the Nevada line, in Twin Falls County. These undoubtedly range back and forth across the State line.

KANSAS

The only antelope definitely reported as existing in Kansas in 1923 was a band estimated to contain about 8 in the extreme southwestern part of the State, in Morton County. According to State Game Warden J. B. Doze they are reported to be more often in Oklahoma than in Kansas, passing back and forth across the line (fig. 7).

At one time Kansas was inhabited by myriads of pronghorns, and for years after the construction of the transcontinental railroads they were a familiar sight to passengers on the trains. In 1923, however, they had become almost exterminated throughout the State.

In a letter dated July 2, 1924, Hal G. Evarts, of Hutchinson, wrote that he had recently received reliable information that in 1916 a herd of 62 pronghorns was ranging about 25 miles northwest of Cimarron, in the Pawnee Creek

breaks. In 1918 he saw seven, which wintered within a mile of the town of Cimarron. In 1921 a band of 16 spent the summer and winter about 15 miles south and west of Garden City. He has not seen them since that time, but is of the opinion that they may still be ranging in the sandhills of that vicinity.

• MONTANA

In the early days the great plains of Montana contained countless thousands of antelope. The present census records surviving herds in 44 districts, mainly in the eastern and central parts of the State, with a total of approximately 3,000 animals. As in many other States, the antelope situation here is precarious and needs prompt attention if the herds are to be perpetuated.

The information given below is mainly the result of inquiries made by Thomas N. Marlowe, chairman of the State fish and game commission; C. A. Jakways, State game warden; by employees of the Forest Service; and especially by O. E. Stephi, R. E. Bateman, and other employees of the Biological Survey. It should be noted that several antelope herds drift back and forth between northern Montana and Canada, particularly from northern Valley and Hill Counties. In severe winters, antelope frequently drift down the Yellowstone Valley into the State from the Yellowstone National Park, Wyo.

Some ranchmen complain of injury to crops by antelope, one complaint relating to damage to alfalfa in Powder River County. Abandonment of ranches by a large number of dry-land farmers has restored more favorable conditions for antelope over considerable areas. Many new settlers are interested in protecting the antelope, but from curiosity frequently kill a single animal to get an opportunity to taste its flesh. A considerable number of the older ranch owners who were in the State during the days when the antelope was one of the common game animals, are now taking an active interest trying to prevent the extermination of the species. In some cases they afford antelope the same protection against hunting on their ranges that they give their cattle. The antelope have learned these sanctuaries, and when shot at elsewhere immediately run to them for safety. Local sportsmen's associations are in position to be very helpful in developing antelope conservation in the State.

Thomas N. Marlowe, chairman of the State Fish and Game Commission, wrote as follows:

"The matter of further protection and propagation of the antelope is, to my mind, a very difficult one. In spite of what we have tried to do in this State, they seem to be, as stated in your letter, on the decrease and practically threatened with extinction. The only possible solution of the matter appears to be the creation of an antelope preserve somewhere in eastern Montana. This should be as thoroughly fenced as the buffalo range near here and the predatory animals destroyed.

"I believe also that a new herd should be started on the buffalo range. [It will be noted below that in September, 1924, a small herd was reestablished on the buffalo range by the Biological Survey.] I believe something can be accomplished along these lines, and if a reserve is created in eastern Montana possibly our department might be able to do something toward financing it, if not too expensive. I am with you in the hope that some solution can be found at the antelope conference to help remedy the situation.

"I am satisfied after having been a member of the State fish and game commission for more than five years that the greatest problem confronting us in this State in the protection of game is the control of predatory animals. If we could exterminate them there would be plenty of game in the State for all

demands, as there is no doubt that predatory animals destroy more than all the hunters put together. Two years ago we framed a law setting aside 25 cents from each hunting and fishing license to cooperate with the Biological Survey in the destruction of predatory animals in connection with the State Livestock Association, but I am frank to say that the amount we are expending in this respect scarcely more than kills off the increase."

The antelope reported from Montana are distributed approximately as follows (fig. 8) :

1. A band of eight is reported in the vicinity of the Sweet Grass Hills, in Liberty County. Antelope are reported to have decreased in this district.

2. Another band of eight ranges along the Marias River, in Liberty County. It is reported that a few years ago several small herds were ranging 20 to 30 miles south of Chester, on the main line of the Great Northern Railroad, in Liberty County, but since then information has been conflicting, and nothing definite has been learned to indicate whether they are still there.

3. A band of 15 antelope south of Galata is said to contain the only antelope remaining in Toole County.

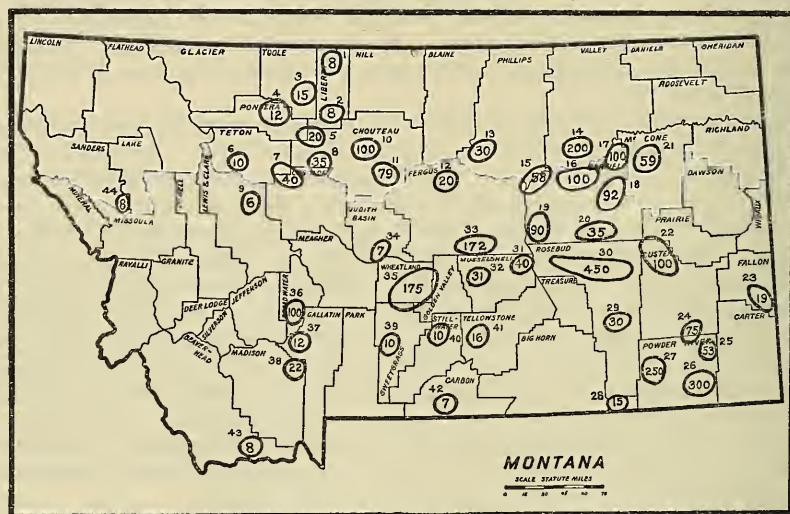


FIG. 8.—Distribution of antelope in Montana; estimated at 3,027, in 44 areas

4. About 12 antelope are still ranging on the Marias River and its tributaries, in Pondera County. Two years ago a band of about 12 ranged on the Marias River 30 miles northeast of Conrad, but people familiar with the district state that they have now disappeared. It is reported that bootleggers in high-powered automobiles passing through this district to Great Falls make a practice of pursuing and killing antelope on the open plains. The residents resent this killing but have been powerless to prevent it. It is reported also that the Conrad and Brady rod-and-gun clubs are interested in the preservation of antelope and will assist in their protection in any way that is practicable.

5. About 20 antelope are reported to range on the Teton River, in Pondera and Chouteau Counties, about 20 miles east of Brady.

6. A band of about 10 antelope is reported about 12 miles southwest of Chouteau on the north side of the Sun River, in Teton County. This band has decreased during the past few years.

7. About 40 antelope are reported to range between Chouteau, Teton County, and Great Falls, in Cascade County.

8. Two bands, numbering about 35, range north of Great Falls, in Cascade and Chouteau Counties.

9. A band of about six is reported to be ranging in the Dry Creek country, about 10 miles southeast of Augusta, in Lewis and Clark County.

10. About 100 are reported north of Fort Benton, in Chouteau County.

11. A band of 19 was reported on February 9, 1924, to range immediately west and north of the town of Montague, Chouteau County, sometimes within half a mile. A few years ago this band was double its present size. Another band of about 60, near the town of Square Butte, is reported to have increased about 10 per cent in the past two years.

12. Three small bands, aggregating about 20, are located near Winifred, in northern Fergus County. One is 10 miles northeast of the town, another 18 miles, and the third is ranging near Armells Creek. The total number of antelope here is slowly decreasing.

13. A band of 30 was reported in 1922 south of the Little Rockies, in southwestern Phillips County.

14. On January 2, 1924, several bands, totaling about 200 antelope, were reported on the range from 20 to 30 miles southwest of Glasgow, in Valley County. A few range around the head of Duck Creek, Brazil, and Dry Runs. The larger bands occupy the country that divides the heads of Little, Beaver, and Lone Tree Creeks and on down the east slope to Willow Creek. The antelope here are reported to be decreasing rapidly and likely to be exterminated unless better protection can be given them. It is reported that antelope occasionally cross into the northern part of Valley County from Canada.

15. A band of about 50 ranges in the Missouri breaks in northwestern Garfield County, and a smaller band of 8 in the adjacent southeastern part of Phillips County between the Little Larb Hills and the Missouri River.

16. About 100 are reported on the Snow Creek Game Preserve in Garfield County.

17. In Garfield County a band of 70 is reported along the Missouri River in Townships 23 and 24, and a band of 30 north and east of Haxby.

18. There are several bands in eastern Garfield County, aggregating about 92 animals, of which 68 occur along Woody Creek, in Townships 40, 41, and 42, and adjacent areas, and about 24 along Big Dry Creek east of Jordan. Several years ago these and other bands in this county were decreasing, but since many dry farmers have left, they are beginning to increase.

19. A band of 60 ranges along Lodgepole Creek from Dilo to the Musselshell River in Garfield County, and another band of 30 occurs farther down in the southwestern corner of the same county.

20. A band of about 20 is located near Cohagen, and another band of 15 ranges in Townships 13 and 14, both in southern Garfield County.

21. In February, 1924, 38 antelope were reported as ranging on the Timber Creek Divide, a small herd of 7 west of Weldon, another numbering 7 near McDonald Butte, 6 on Jawbone Coulee, and a single buck on the Big Dry, totaling 59 animals in McCone County.

22. Frank Hamlick, a deputy State game warden at Kinsey, Custer County, wrote on January 21, 1924, that 49 antelope were living in his pasture, and that various other bands were located within 15 miles, which in the aggregate amount to about 100 animals. He is doing all he can to protect them, but they are being killed by hunters.

23. Three small bands, aggregating about 19 animals, occur in southeastern Fallon County, where they are reported to be decreasing.

24. A band of 75 is reported to range on Mizpah Creek, in southern Custer and northern Powder River Counties.

25. C. A. Hatterschied wrote in February, 1924, that in the preceding fall he counted a herd of 53 antelope on Timber Creek, in Powder River County.

26. In January, 1924, P. E. Fannigan, of Graham, wrote that several herds of antelope occur in the country lying east of the Big Powder River, in southern Powder River County. He considers that they aggregate more than 300 animals. One neighbor counted 270 antelope in his pasture on one occasion last year. They do not appear to be increasing, but some of the farmers complain that they are eating their alfalfa. From the reports, it is probable that there are other antelope in this section of the State, but details are lacking. C. A. Hatterschied reports seeing a herd of 47 on Horse Creek in the fall of 1923.

27. Bands totaling 250 range on the Custer National Forest southeast of Ashland, in Powder River County. B. W. Hogan, of Ashland, wrote that when he went there in 1910 there were only 3 antelope in the entire Custer National Forest. These were well protected by ranchmen and have increased to the present herd. They are often seen in bands of from a dozen to more than

100. The Custer National Forest appears to be ideally adapted to their needs.

Powder River County appears to have the largest number of antelope in any area of that size in the State. R. F. Tarbell stated that the largest band on a ranch in the southern part of the county numbered 57. This increased somewhat during 1923, but, as a whole, the antelope have barely held their own during the past 10 years. At the present time they are not being molested and undoubtedly are increasing.

28. A band of about 15 is reported in the extreme southeastern part of Big Horn County, on the Tongue River, near Decker. It is being protected and is slowly increasing.

29. A band of about 30, which is reported to be increasing in numbers, is ranging south of the Yellowstone on Otter and Beaver Creeks in southern Rosebud County.

30. North of the Yellowstone River, along Stella, Hay, Wolf, and Cottonwood Creeks, and also between Forsyth and Melstone, are a number of bands of antelope varying in size up to nearly 200 animals, which aggregate about 450. They are said to be holding their own or increasing in numbers.

31. In a district about Melstone, in Musselshell County, three small bands, totaling about 40 animals, are said to be decreasing.

32. A band of 31 is reported on the Gumbo Flats north of Roundup in Musselshell County.

33. A band of 172 was counted along Elk River on the Jack Rowley Ranch, about 50 miles southeast of Lewistown, in Fergus County. Mr. Rowley states that for the past 10 years from 100 to 125 antelope have been ranging on the ranch about 50 miles southeast of that town. During the fall of 1923 he counted 172 in one band, which apparently covered the entire number. He states that they ordinarily run in three or four bands, but occasionally unite. They have many young; but, although efforts have been made by the owners of the ranch to protect them, they continually stray off and are shot by hunters. When fired at, those not hit usually seek safety in the meadows on the ranch where they seem to appreciate the fact that they are protected. Mr. Rowley believes that since so many dry farmers have left that section of the State, conditions are more favorable for the antelope, which are likely to increase in numbers.

34. A band of 7 is located in the foothills of the Big Snowy Mountains south of Moore, in Judith Basin County.

35. About 175 antelope are located mainly in Wheatland County. Of these, two bands of about 20 each range near Rothiemay in western Golden Valley County, about 80 on the Winnecock Sheep Ranch, 5 to 10 miles southwest of Shawmut, and a few small bands numbering about 30 northwest of Twodot, the last-named bands being all in Wheatland County, also 25 near Porcupine Butte, northern Sweetgrass County. It is reported that the antelope in this area have been decreasing rapidly since 1908 through hunting from automobiles.

36. About 100 antelope ranged near Radersburg, Broadwater County, in 1923. It is stated that some of these can be seen from the main road at almost any time.

37. A band of 12 was reported near Three Forks, in Gallatin County, in 1912, but no information has been received concerning them since.

38. About 22 antelope are reported to live on the old Green Ranch immediately west of Madison River near the mouth of Cherry Creek, in Madison County. This band has decreased during the past 15 years.

39. A band of about 10 is located on the Little Timber and Duck Creek Ranges in Sweetgrass County.

40. A band of 10 ranges near Gibson, in the Big Coulee Country, in northern Stillwater County.

41. Several bands, numbering at least 16, range about 20 miles northwest of Billings, in Yellowstone County.

42. A band of 7 is reported on Lone Creek, near Red Lodge, Carbon County.

43. The only antelope reported in Beaverhead County is a band of 8 ranging on Red Rock and Black Tail Creeks.

44. Eight antelope were placed on the National Bison Range in September, 1924, by the Biological Survey, in cooperation with Doctor Brownell, of San Francisco, and Doctor Hornaday, of the Permanent Wild Life Protection Fund. These antelope were from the Washoe Antelope Reservation in northwestern Nevada, where they were caught as newly born fawns in the spring

of 1924. The antelope placed on this range by the Boone and Crockett Club in 1911 increased to 64, but all are believed to have been killed by predatory animals in 1922.

NEBRASKA

Of the countless thousands of antelope which once roamed the plains of Nebraska but 10 small bands remain, containing a total of about 187 animals. As in Kansas and some other western States, for many years following the completion of the first transcontinental railroad, passengers through Nebraska had the pleasure of observing many antelope from the train windows. With the increasing occupation of the State by farmers and stockgrowers the pronghorn has been reduced to the present insignificant numbers.

Only a single attempt appears to have been made to establish and maintain under confinement a herd of antelope in this State. This was done in September, 1924, when the Biological Survey, in cooperation with Doctor Brownell and Doctor Hornaday, as detailed elsewhere, placed 10 young antelope from northern Nevada on the Niobrara Reservation, a Federal game refuge near Valentine. Conditions there appear to be well suited to antelope,

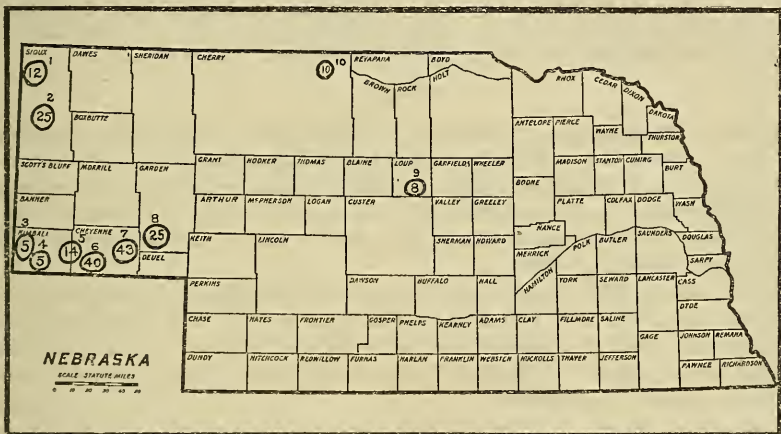


FIG. 9.—Distribution of antelope in Nebraska, estimated at 187, in 10 areas

and it may be possible to build up an interesting herd. In order to insure the perpetuation of these beautiful animals in Nebraska, another herd might well be established elsewhere in the State.

The occupation of Nebraska for farming purposes is so complete that there is little hope of a herd being maintained there except under fence. Safe free range for antelope in this State is a thing of the past.

In a letter dated March 12, 1924, George Bird Grinnell wrote that three or four years ago a band of about 40 antelope was located somewhere along the North Platte north of Bridgeport, Morrill County. According to the latest accounts he had they were rapidly decreasing.

Supervisor Jay Higgins, of the Nebraska National Forest, supplied information in the spring of 1922 that there were bands of antelope in Scotts Bluff, Banner, and Kimball Counties, and added: "We secured three convictions for killing antelope in Scotts Bluff and Kimball Counties."

The antelope bands existing in Nebraska in 1922 and 1923 were distributed as follows (fig. 9):

1. A band of about 12 reported in 1922 as near the 33 Ranch, in Sioux County, near the Wyoming line.

2. A band of about 25 ranged near Agate, in Sioux County, in 1922. These have existed in about the same numbers for the past 10 years.

3. A band of about 5 was reported in 1922 about 10 miles west of Bushnell, in Kimball County.

4. A second band of 5 was reported in 1922 near the State line, south of Kimball, in Kimball County.

5. A band of 14 was reported in 1922 between Dix and Potter, on the border between Kimball and Cheyenne Counties. Their numbers for some years have remained about stationary.

6. A band of about 40 was reported in 1922 as ranging about 18 miles south of Sidney, in Cheyenne County. For some time this band has about held its own.

7. A band of 43 was reported in the spring of 1922 as grazing in fields near Sunol, in eastern Cheyenne County. The farmers complained of this invasion of their wheat fields by antelope and requested information of the Forest Service as to what might be done to control them.

8. A band of 25 was reported in 1922 about 12 miles south of Lisco, Garden County. This herd had about held its own for some time.

9. A band of 8 was reported in March, 1924, about 15 miles north of Sargent, in Loup County.

10. Ten young antelope, 6 females and 4 males, were placed on the Niobrara Game Reservation in September, 1924, by Doctor Brownell, of San Francisco, and Doctor Hornaday, of the Permanent Wild Life Protection Fund, in cooperation with the Biological Survey. These antelope were part of the fawns captured in northwestern Nevada in the spring of 1924, as already detailed.

NEVADA

Formerly antelope were plentiful over all the Great Plains and deserts in this State. They are now limited to about 11 comparatively small areas. In the northern and northwestern parts of the State occur great areas sparsely occupied by man, where conditions are still favorable to these animals. As a result, some of the largest herds to be found in the West still survive there, aggregating more than 4,200.

Legal protection for antelope in Nevada has undergone some changes in the past few years which it will be of interest to record. The close season for antelope was lifted in Nevada by an act approved March 23, 1921 (amending chapter 234 of the act of March 27, 1917, as amended by act approved March 4, 1921), providing as follows:

"Sec. 42. It shall be unlawful to kill, catch, trap, wound, or pursue with the intent to catch, capture, injure, or destroy any deer or antelope at any time during the year other than during such 30-day period to be known as the open season between September 15 and December 15 of each year as may hereinafter be designated for the respective counties by the boards of county commissioners thereof under the provisions of section 50 of this act; provided that there shall never be any open season on deer without horns and that during such open season of each year it shall be unlawful to kill, catch, trap, wound, or pursue with the intent to catch, trap, injure, or destroy more than one deer with horns and one antelope with horns; and provided further that in all counties in which no designation to the contrary shall have been made by the county commissioners prior to the 1st day of August of any year, the open season for deer with horns or antelope shall be from October 14 to November 12, both dates inclusive."

An act approved March 21, 1923, restored antelope to the protected list until 1930, in the following terms:

"Sec. 9. It shall be unlawful at all times to take any mountain sheep, goats, elk, or antelope until January 1, 1930."

After the opening of the season on antelope in Nevada in 1921 there was a feeling among some of the county commissioners in the northern part of the State that an open season was called for. E. R. Sans, predatory-animal inspector of the Biological Survey, working with the Washoe County Game

Protective Association, pointed out to the boards of supervisors in Humboldt and Elko Counties the undesirability of an open season on antelope, and as a result the season was closed by them for two years. In Washoe County the board of supervisors felt the technical requirements of the law called for an open season, but were so well convinced of the undesirability of permitting antelope to be killed in any numbers that they limited the open season to one-half hour, extending from 7.30 to 8 a. m., November 10. It is obvious that under such conditions no antelope were legally killed in Nevada that season.

The information concerning the distribution and numbers of antelope in Nevada has been furnished mainly by Mr. Sans and by Supervisor Alexander McQueen, of the Humboldt National Forest. Mr. Sans has been extraordinarily successful in promoting antelope protection in Nevada. His friendly cooperation with the State authorities and the active part he took at the request of the governor in helping to locate and outline the antelope refuges in the northern and northwestern parts of the State have been a major service to the conservation of these animals.

The distribution of antelope in Nevada is approximately as follows (fig. 10):

1. This area is the Washoe County State Game Refuge (Pl. V, fig. 2). The number of antelope within its limits is estimated by resident stockmen at from 2,000 to 2,500. E. R. Sans wrote:

"Predatory Animal Hunter R. W. Young, stationed at the Thomas Dufurrena ranch in the Thousand Creek district of Humboldt County, reported on January 17,

1924, that he saw not less than 1,000 antelope in the course of a day's travel in that neighborhood, and from reliable reports we gather that this is the wintering ground for these animals.

"T. B. Harriman, one of our predatory-animal trappers working in northern Washoe County, reported December 19, 1923, a band of from 600 to 700 antelope migrating to their winter range in the High Rock Canyon. This is the largest band we have had any notice of wintering in High Rock Canyon. There have always been a few coming into this sheltered district to winter, but this winter an unusually large number is there."

Further interesting information concerning the antelope on this game refuge is contained in statements received from Mr. Sans, which are set forth in the account of his capture of the young antelope for restocking purposes during the present season.

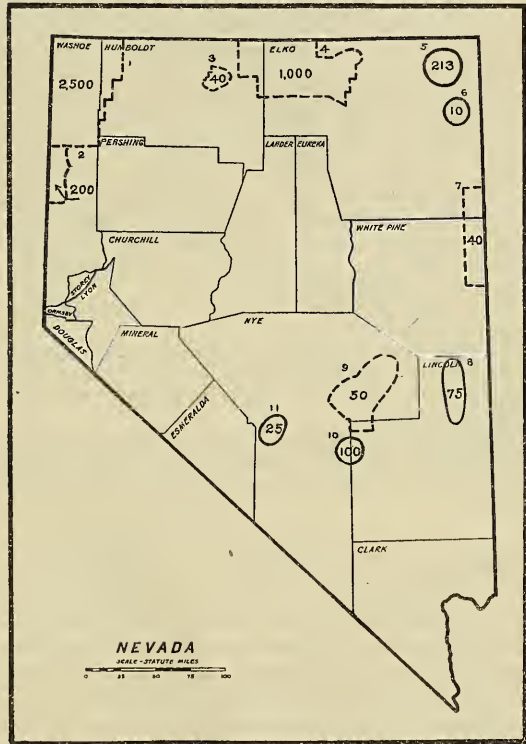


FIG. 10.—Distribution of antelope in Nevada, estimated at 4,253, in 11 areas. Game refuges indicated by broken lines

2. This area covers the Smoke Creek antelope refuge of Washoe County, south of the main Washoe County refuge. Mr. Sans wrote:

"From reliable information I learn there are about 1,000 antelope ranging from Willow Creek, northeast of Susanville, in California, to Smoke Creek, in Nevada. The larger part of these appear to range in Secret Valley and the tablelands in Nevada to the railroad to Amadee and Ravendale, Calif., on the north."

These herds include those recorded for Lassen County, Calif., and those which remain permanently in Nevada. On account of the uncertainty as to the exact number in Nevada, they have been placed at 200 animals, although at present they must exceed 1,000, owing to the California herds having temporarily entered this area, as set forth in the account of the California antelope.

3. About 40 antelope are reported to range on the Santa Rosa State Recreation Ground and Game Refuge in eastern Humboldt County.

4. Various bands, aggregating about 1,000 antelope, are reported to occupy this area, which includes the Humboldt State Recreation Ground and Game Refuge, in Elko and Humboldt Counties. This area is the southern extension of the Owyhee Desert from across the boundary in Idaho. Some of the antelope range back and forth across the Idaho line. These bands are said to be holding their own, if not increasing.

5. This area contains bands numbering, respectively, 29, 43, 71, and 70, by actual counts, ranging on Nine Mile Flat, 16 miles east of Contact and between the Bad Lands and Loomis Creek, in Humboldt County. These 213 are said to have increased from 20 during the last seven years.

6. A band of about 10 ranges near Cobre, in Elko County.

7. This area covers the White Pine State Recreation Ground and Game Refuge (No. 12), in White Pine and Elko Counties. A band of 40 antelope is reported to be ranging there.

8. A band of about 75 ranges in Duck Valley, from Geyser to Pioche, in Lincoln County.

9. This area includes the Grant State Recreation Ground and Game Refuge (No. 4) in Nye County. Several small bands of antelope, estimated to aggregate from 35 to 65 animals, are said to range within this area in Railroad Valley.

10. A band estimated at 100 was seen during the spring of 1923 near White Blotch, Lincoln County, and in the adjacent parts of Nye County.

11. A band of 25 is reported to range in Wild Horse Valley, southern Nye County.

NEW MEXICO

Antelope in New Mexico are decreasing, but up to the fall of 1923 they were still found in 31 areas, with an estimated total of 1,682 survivors from the vast herds which once occupied this region. Details concerning their numbers and distribution in this State set forth below are largely the result of careful investigations made to March 1, 1924, by L. C. Petree, chief deputy in the State department of game and fish. In addition information has been supplied by employees of the Forest Service and of the Biological Survey and by individuals in the State. District Forester Frank C. W. Pooler, of Albuquerque, submits some interesting ideas on antelope conservation, as follows:

"I imagine everybody agrees that the nucleus of any scheme should include several Federal game preserves covering herds like the one proposed in adjacent parts of Oregon and Nevada. Such preserves, however, can not go further than to serve as a kind of rock-bottom insurance against total disappearance. The big problem is to secure an effective care of the scattered herds running on all kinds of land under all kinds of jurisdictions.

"Could not the Biological Survey be designated by the proposed convention as the central agency to perform the following steps with respect to each herd for which there appears to be a reasonable chance of perpetuation:

"(1) Determine the number, range, and condition of the herd.

"(2) Assign custodianship of the herd to some one party. This might be the Forest Service, the State game department, some stockman, or possibly some game protective association.

"(3) Confer with such agency as to the step necessary to insure perpetuation; such steps might include the establishment of State game refuges, the offering of rewards against killing, pledges on the part of the stockmen to exercise rigid jurisdiction over their employees, pledges of winter feeding, or arrangements for predatory-animal control.

"(4) Ask for the necessary cooperation from the necessary parties to assure the execution of the measures decided on under the preceding paragraph (3).

"(5) Require from the custodian at least an annual report on the condition and needs of the herd.

"Let me offer one example of how the foregoing scheme would work. On Diamond Creek in the Gila Forest is a herd of about 25 animals, which have lodged there in timbered country since a blizzard drove them out of the San Augustine Plains about five years ago. This herd has plenty of feed and water.

very fair protection against predatory animals, and no great likelihood of illegal killing except during the deer season, when they are occasionally mistaken for deer by hunters. A special warning to all hunters in that locality, supplemented by a little extra patrol during the 10 days of the hunting season, would, I think, cause them to start increasing. The Forest Service would, I think, assume the special custodianship of this herd and would have the cooperation of the stockmen. If authorized by the forester it might be that we could even require certain special precautions by the two or three stockmen affected against any of their employees damaging this herd.

Should predatory animals get worse, we would doubtless have your cooperation whenever we reported the situation. The main thing would be that somebody would assume responsibility for doing all reasonable and practicable things for the herd."

Mr. Pooler's contribution contains some very practical suggestions, some of which might be utilized as the program for antelope conservation develops.

Antelope for many years have been protected on the well-known Bell ranch, where there has been a standing offer of \$50 reward for the arrest of anyone found hunting on these lands; but under this protection they have not increased so rapidly as might be expected, probably owing to the depredations of predatory animals and eagles.

The bands of antelope in New Mexico are located as follows (fig. 11):

1. About 50 antelope range in southeastern Colfax County.
2. A band of 14 was reported in February, 1924, in the Eklund pasture, 15 miles northwest of Clayton, Union County.

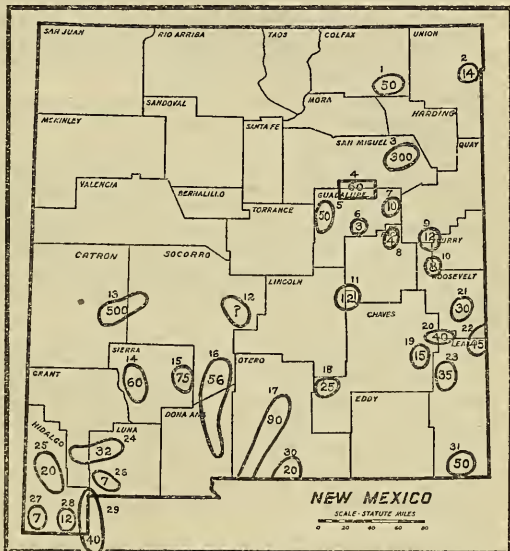


FIG. 11.—Distribution of antelope in New Mexico, estimated at 1,682, in 31 areas

3. About 300 antelope are estimated to occupy the area of the original Bell ranch, eastern San Miguel County, now partly owned by the Tom B. Owens Co. and by Dan C. Trigg, jr. This is the largest number of antelope in any restricted district in the State. The first-hand information here presented concerning these animals shows the need of a careful survey of the situation in this district as a basis for further conservation measures. The friendly attitude of protection toward the antelope by the owners of the ranges indicates possibilities of building up here considerably larger herds than now exist. Owing to the large size of this area there has been some difficulty in getting definite information concerning the present situation. C. M. O'Donel, manager of the Bell ranch, under date of July 20, 1923, supplied the following:

"The sum of the reports from employees in various parts of the range gives the number of antelope within the present boundaries of the ranch as 217. Naturally this can not be an accurate count, though the habit of antelope to 'locate' in bunches makes it more accurate than would probably be the case with other varieties of game. * * *

"I believe that antelope are increasing on this range only very slowly, if at all. My opinion is that their natural enemies, of which perhaps the eagle is the worst, keep down the increase by destroying the young. I believe we had as many, if not more, antelope here when I first came to the ranch 25 years ago."

Inquiry was instituted among the purchasers of parts of the original Bell ranch, with the following results:

The Tom B. Owens Co. wrote:

"We hardly know how to arrive at an estimate of the number of antelope on our property, but think around 100 to 150 old ones, with possibly a fawn crop of 50 this year.

"The antelope on our place as well as on the Bell ranch are found on the level open valleys and rarely go into the mountains for any reason. We have, it seems, a surplus of bucks and often see them off by themselves, they having been whipped out of the herds by the younger and stouter bucks.

"We do not know of any other section of the country where the antelope are as often seen as on these ranches, and we never take any kind of drive or ride over our pastures without seeing several bunches of various numbers, from 2 to 20."

Dan C. Trigg, jr., who now owns a part of the original Bell ranch, wrote:

"A few antelope stay in my pasture all the time. I have seen as many as 26 in a bunch. There have always been two separate bands in different portions of my ranch. They are more or less migratory and have a habit of crossing into the Bell ranch, which joins my holdings for several miles."

4. Bands totaling about 60 antelope are reported from the ranches of Senator A. A. Jones and of John Hicks, in San Miguel and Guadalupe Counties.

5. A band of 50 is reported in western Guadalupe County.

6. Three antelope are on the Ed. Morrow ranch, in southern Guadalupe County.

7. A band of 10 is reported in eastern Guadalupe County.

8. Four antelope are reported on the Buckeye ranch, near Taft, in northern De Baca County.

9. A band of 12 is on the Charles Orr ranch, near the cornering parts of Roosevelt, Curry, and Quay Counties.

10. A band of 8 occurs on the C. S. Hart ranch, near the borders of Roosevelt and Curry Counties.

11. A band of 12 is near the bordering corners of Lincoln, De Baca, and Chaves Counties.

12. A band of antelope is reported as living in southeastern Socorro County, but the number is not given.

13. Herds aggregating 200 or more are reported as ranging on the San Augustine plains, in Catron and Socorro Counties. This number was verified by actual count reported by the Magdalena Game Protective Association, but those familiar with the situation believe that there are many more than that number in this district. G. W. Evans, of Beaverhead, states that 200 antelope, by actual count, live on his 50,000-acre ranch in the southwestern portion of San Augustine plains, in Catron County, within the general area reported by the Magdalena Game Protective Association. It is obvious that there are in this Great Plains region many more antelope than those here listed, possibly 500 in all. Formerly the San Augustine plains were a favorite resort for thousands of antelope.

14. A band of about 60 ranges in western Sierra County,

15. Clyde L. Grow, reservoir superintendent of the Reclamation Service, wrote from Engle, N. Mex., on September 12, 1924, reporting between 50 and 75 antelope on the east side of the Elephant Butte Reservoir, in the Cristobal Mountains, in eastern Sierra County. He added that they were fed during the deep snow all the preceding winter by the Victoria Land & Cattle Co. and are in good condition. They range to the vicinity of Engle, where they are sometimes seen by passengers on the Santa Fe Railroad trains. In 1883 the writer had the opportunity to observe personally a very considerable number of antelope ranging the plains about Engle, particularly to the east and north. The proprietor of the single hotel and general store there at that time kept a pack of greyhounds which he fed on antelope meat. His sole amusement in this isolated place was to drive out with a buckboard on the open plains, accompanied by his greyhounds, until he found a band of antelope, when the greyhounds were sent in pursuit while he followed until the dogs had pulled down and killed one or more of the animals, which he carried back for dog food.

16. A band of 56 antelope was reported to be ranging between White Sands and the Organ and San Andres Mountains, in Socorro and Dona Ana Counties.

17. In southwestern Otero County 90 antelope are reported by Oliver Lee, manager of the Sacramento Land & Cattle Co., and others.

18. A band of 25 ranges about the headwaters of the Felix River, in southwestern Chaves County.

19. The "L. E." pastures in eastern Chaves County are occupied by a band of 15.

20. H. E. Crosby, of Kenna, reports 40 antelope living in the pastures of the Crosby ranch in eastern Chaves County.

21. A band of 30 is reported ranging on the Littlefield ranch, on the Staked Plains, in central Roosevelt County.

22. In northeastern Lea and southeastern Roosevelt Counties 45 antelope are reported ranging on Bakers Flats and across into adjacent parts of Texas. A small band, the number not specified but reported to have been living in northern Lea County for several years, has raised no fawns, owing to the depredations of predatory animals. In the spring of 1923, following a co-operative campaign against these destructive pests by the Biological Survey and the State, a number of fawns survived and this herd may now increase.

23. A band of 35 antelope is reported in western Lea County.

24. There is a band of 10 near Cow Springs, in southern grant County, and one of 22 on the Antelope Plains of western Luna County.

25. A band of 20 is reported as ranging in the San Luis Valley, in Hidalgo County.

26. A band of 7 is in southwestern Luna County.

27. A band of 7 is reported also in the Juniper pastures, Animas Valley, in Hidalgo County.

28. In 1922 a band of 12 was reported in Playas Valley, in Hidalgo County.

29. About 40 antelope range in extreme southeastern Hidalgo County, some of which cross into the adjacent part of northwestern Chihuahua.

30. Twenty antelope range from southern Otero County south into Texas.

31. About 50 antelope occur in San Simon Range, in southern Lea County.

NORTH DAKOTA

Antelope have almost disappeared from North Dakota. The remaining herds now number only five and aggregate 225 animals. Their future appears to be extremely doubtful unless a game preserve can be established wherein they may be safeguarded. The information concerning antelope in North Dakota has been obtained by H. L. Rice, of the North Dakota State Game Commission, and R. Scott Zimmerman, in charge of rodent-control work in the State for the Biological Survey.

The distribution of the herds is approximately as follows (fig. 12):

1. In September, 1924, 60 antelope were reported as ranging from northwestern Dunn County into the adjacent part of McKenzie County.

2. A band of 9 was reported in September, 1924, in southwestern McKenzie County.

3. About 75 are reported in adjacent parts of central Golden Valley and Billings Counties. This is the largest band reported in the State. William McCarthy, who owns 11,000 acres of rough, rolling land in the heart of the Bad Lands along the Missouri River, which affords a natural range for game, writes that when he came into possession of the range in 1910 there were about 15 antelope there. Much hunted, they sought and were given every protection in his pastures, where they found running springs and flowing wells with an abundance of grass, and as a result have become very tame.

4. Bands numbering 55 were reported in September, 1924, in the Bad Lands of the Little Missouri River in Slope County.

5. In September, 1924, a band of 26 was reported from southwestern Bowman County.

OKLAHOMA

Of the vast number of antelope once roaming the prairies of Oklahoma only a single native band, containing 5 or 6 animals, was reported as surviving in 1923, and the small band on the Wichita National Game Preserve, in Comanche County. (See Pl. I.)

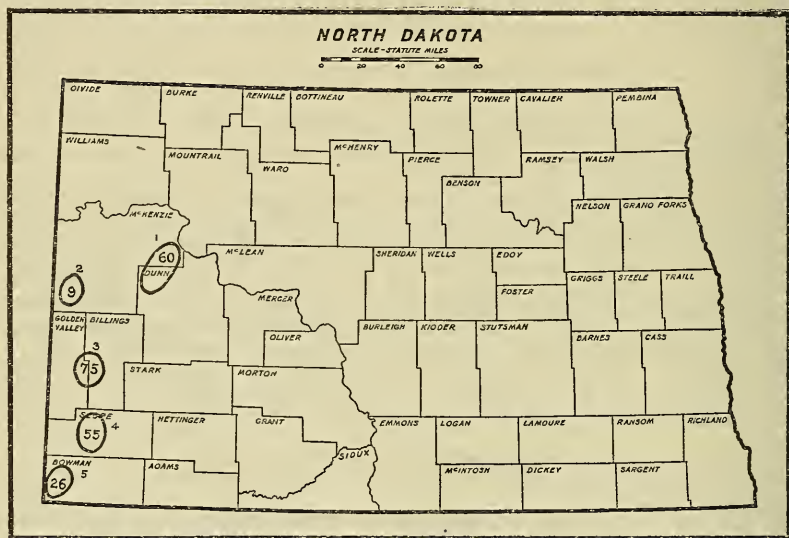


FIG. 12.—Distribution of antelope in North Dakota, estimated at 225, in 5 areas

In December, 1910, and January, 1911, the Boone and Crockett Club transported 9 antelope from the Yellowstone National Park herd to the Wichita National Game Preserve. This experiment had an unfortunate ending, since all the animals died during the next few years. Another attempt was made in the fall of 1921 by the American Bison Society to establish a herd on this preserve by placing there 10 animals which had been purchased at Brooks, Alberta. Six of these died shortly afterwards, and in the fall of 1922 the Bison Society placed 6 more there from the same source. Of these 5 died shortly afterwards, leaving during the winter of 1922-23, 5 survivors from the original transplantings of 16. In the spring of 1923 the 3 females each gave birth to a pair of young, which were safely reared. This was duplicated in the spring of 1924, bringing the number in the herd to 17. The handicap which at first existed appears to have been overcome, and the outlook is favorable for the establishment there of a good herd.

The following interesting quotation from a letter from District Forester Reed, United States Forest Service, dated June 20, 1923, gives an idea of the vicissitudes undergone by the antelope during the last two introductions:

"We have just received word from Mr. Rush that there is but one survivor of the six shipped to the Wichita last fall. This survivor is a buck. Two of the antelope died from the effects of ticks and two have disappeared. Mr. Rush surmises that the coyotes got in and killed them while they were in the little bull pasture. Later they were moved into the buffalo yard, and the only female left ran headlong into the gate and broke her neck. Of the antelope shipped two years ago, one 2-year old buck and three 2-year old does remain. This reduces the herd to 5 adult antelope.

"Mr. Rush reports that the 3 does now have 2 fawns each. This brings the herd up to 11 head, and Mr. Rush says that he had excellent luck with them. It is to be hoped that the fawns born in captivity on the Wichita will survive the vicissitudes which decimated the original shipment made by the



FIG. 13.—Distribution of antelope in Oklahoma, estimated at 23, in 2 areas

American Bison Society. Since we have 11 antelope on the Wichita, it does not seem necessary to seek further assistance from the American Bison Society at this time. We will, however, take the best care of the remaining antelope. We are satisfied that Mr. Rush has done his best, and it seems that we have a fighting chance to secure a herd of antelope on the Wichita."

The location of the two bands of antelope now in Oklahoma may be stated as follows (fig. 13):

1. A single band of 5 or 6 animals is living in the Ford pastures in northeastern Cimarron County, where it is protected. A band of about 8 animals, reported to range in Morton County, southwestern Kansas, is said to spend part of its time across the line in Oklahoma, which would take it into Cimarron County. The relations between these two herds have not been ascertained. For convenience the 8 animals are credited to Kansas and make up the only known surviving antelope in that State. Apparently the only survivors of these animals in both Oklahoma and Kansas are in the adjoining counties of the extreme western parts of these States.

2. During the summer of 1924 a herd of 17 antelope was on the Wichita National Game Preserve. This is an increase of 12 animals from the 5 survivors of 25 animals imported in previous years by the Boone and Crockett Club and the American Bison Society.

OREGON

Southeastern Oregon forms part of a rough, rocky desert covering also northern Nevada and southwestern Idaho, on which natural conditions have been exceedingly favorable for antelope. This region constitutes one of the few areas in the United States where large herds of these animals numbering hundreds still continue to congregate during the winter season. Southeastern Oregon covers so large a territory and the herds in it are so widely scattered that it has not been practicable definitely to locate them and ascertain their numbers. For this reason an area has been marked on the accompanying map (fig. 14) covering the main antelope territory, within which it is estimated that the different herds contain an aggregate of not less than 2,000 animals. Most of the definite information concerning antelope in Oregon has been supplied by Stanley G. Jewett, of the Biological Survey, and W. L. Finley, of the National Association of Audubon Societies.

There is no question that antelope have increased in Oregon during the past few years, and although year by year a considerable number have been killed by poachers, yet this has not been sufficient to overcome the increase. It has been reported that the climatic conditions were especially favorable for them during the winter and spring of 1923-24, and that an unusually large number of young were born. Water and range conditions were worse in this district during the summer of 1924 than for years. Cattle owners moved all their stock from this range about the middle of August and as a result conditions were made more favorable for the antelope.

Old Fort Warner and the neighboring Desert Lake appear to be centers of abundance for antelope. Stanley G. Jewett, leader of the predatory animal control work of the Biological Survey in Oregon, writes that while he was there during August, 1924, antelope were in sight practically all the time, and he is confident that on August 16 and 17 he saw not less than 500 within a radius of 15 miles. In a letter dated September 2, 1924, Mr. Jewett stated:

"I am sorry to report that a number of fawns have been found dead. Jacobs reports about 20 dead within a radius of 15 miles from old Fort Warner. An old doe was sick near camp while I was there. She acted much like an alkali cow. This condition has probably been brought about by the extreme drought and the fact that the does have not had enough nourishment properly to feed their young. Range conditions are so bad that the big cattle companies have taken all their cattle from that range."

Such adverse conditions must prevail not only over eastern Oregon but into the adjacent parts of Nevada and Idaho. What the outcome will be as to the antelope in this great area is a serious question, since it is one of the greatest centers of surviving antelope in the entire West.

For a number of years various persons interested in the conservation of antelope have been advocating the establishment of a Federal antelope refuge in southeastern Oregon. Details concerning this project are set forth elsewhere in this bulletin.

The present distribution of antelope in Oregon is as follows (fig. 14):

1. During July, 1924, a single antelope was seen at different times near Antone, in Wheeler County, which is considerably outside the general distribution area of antelope at the present time and may indicate a gradual extension of range into formerly occupied territory.

2. In July, 1924, an isolated herd of about 13 was observed on Twelve Mile Creek in the southeastern part of Crook County and the northwestern part of Harney County.

3. A herd of about 20 was ranging in July, 1924, on the northeastern side of Harney Valley from Saddle Butte north to old Camp Harney in northern Harney County.

4. This large generalized area contains nearly all the surviving antelope in Oregon. The number has been roughly estimated here at 2,000, although it may be considerably in excess of this. They are distributed in many herds, the largest of which is believed to number nearly 1,000 and is located in southern Harney County and southeastern Lake County, from which it may range across into Nevada. Two other herds, estimated to contain about 500 each, range, one in southern Malheur County across the boundary into Idaho and into Nevada, and the other in northern Lake and southern Deschutes Counties. The many dry-farming homesteaders have left the high desert country of southeastern Oregon during the past few years, and the antelope have been gradually going back into their former range. During the summer of 1924, seven grown antelope and one fawn were seen a number of times in the jack-pine timber about Button Spring and Sand Spring, where they watered, in the extreme northeastern corner of the Deschutes National Forest. Another recent extension of range is in the vicinity of Fife in southern Crook County and along the upper stretches of Silver Creek in northwestern Harney County.

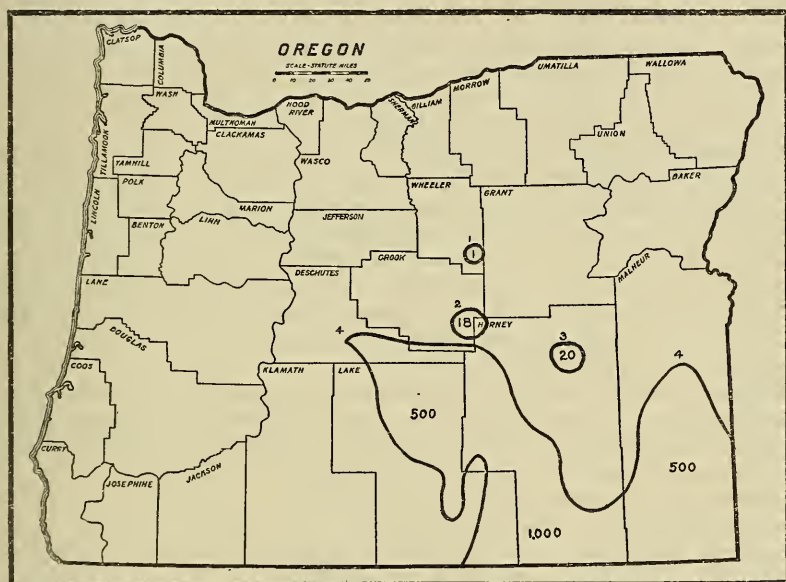


Fig. 14.—Distribution of antelope in Oregon, estimated at 2,039, in 4 areas

There small bands of from 10 to 20 have been seen at various times about Benjamin Lake and on Wagontire Mountain.

The antelope occurring in the northwestern part of their range in this region are scattered in small bands, owing to the extreme scarcity of water. They practically all water at the springs on Grays Butte, Christmas Lake, Button Spring, Sand Spring, and the southern slope of Hampton Butte, and ordinarily at Glass Butte, but the latter spring has been absolutely dry the present season. Antelope in the extreme southeast bordering the Idaho line are in a better watered region and are much scattered along the tributaries of the Owyhee and about many springs in that area.

SOUTH DAKOTA

Senator Peter Norbeck and State Game Warden H. S. Hedrick are taking a very active interest in the conservation and building up of the herds of antelope in South Dakota. Concerning the practical side of this question, Senator Norbeck's remarks at the antelope conference in Washington on December 14, 1923, are much to the point. He stated:

"I think the situation in our State is very largely the same as in other Western States. The antelope is exterminated everywhere except in about one-quarter of the area. Together with the State game warden I spent a little time this summer going over 5 or 6 counties and we were surprised that there were a number of small bands of antelope surviving. They remain in certain areas which are probably more favorable for them. The bands were generally from 4 or 5 up to 20 or 30. One band of 85 was seen—a really fine-looking, healthy lot of animals. They had been ranging in the same neighborhood for about the last 20 years. * * *

"South Dakota is all settled. There is very little Government land left. The land we need for the antelope refuge is nearly all patented, though not all occupied. The State has a fenced game preserve of 40,000 acres, but this is built in the foothills of the mountains and is not a suitable range for antelope. While I was there recently the State game and fish commission passed resolutions taking the first steps toward the establishment of an antelope preserve in the antelope country, with the plan of fencing in 5 or 6 sections of land to include some of the larger bands that we saw during my recent trip. This should take in from 50 to 100 antelope as a start. I am sure that something substantial will come from this."

Senator Norbeck informs the writer that this game refuge will be primarily for antelope, but that with the addition from the Federal forested lands it is desired to establish here herds of elk, buffalo, and possibly some other game animals. The headquarters of this fine game refuge is to be at Reva Gap, located on the main line of an important highway. This locality is not only one of natural beauty but one of historical interest, having been the scene of the battle of Slim Buttes with the Indians 50 years ago, fought under Gen. Anson Mills, then a captain. Parts of this game preserve are hilly, with thin forests; the rest of it is open prairie.

The largest number of surviving antelope are located in the northwestern corner of the State, where, in Harding County, a new State antelope refuge has been established in accordance with legal authorization granted at the time Senator Norbeck was governor. In regard to the plans for this refuge Senator Norbeck wrote under date of July 24, 1924:

"An antelope preserve has been established in the northwest corner county of the State by action of the State game and fish commission, and additional Federal lands have been set aside for the purpose by recent act of Congress.

"The area includes considerable State land, but some private ranches will have to be purchased. The plan is to have an inclosed preserve of about 15,000 acres. The first fence, which is now under construction, incloses an area 3 miles square. It is believed that from 100 to 150 antelope can be gathered into this inclosure, as that number of animals range over this area and in the immediate neighborhood.

"The State has set aside \$20,000 for this work. Additional funds will be required, but same will be provided in the next few years. It will probably take from 3 to 5 years to work out the complete plan but I believe that we have made a very good start."

On August 8 Senator Norbeck wrote that after further consideration on the ground it has been agreed immediately to enlarge the fenced area on the new antelope refuge to include 15 or 16 sections of land.

Under date of September 9, 1924, he added:

"We are going ahead in splendid shape with our antelope preserve. The material has already been purchased for the inclosure of some 15 or 16 sections

of land. The fenced area will be approximately 4 miles square and will cover some of the present antelope range.

"Whether it will be 15 or 16 sections depends on the purchase of a ranch, for which negotiations are now under way. Most of the land inside the inclosure is owned by the State of South Dakota. An 800-acre ranch, with improvements, located in the center of the area, has already been purchased by the State.

"The inclosure will cover approximately half of the proposed game preserve, it being the intention of the commission to enlarge it in a year or two by adding an area 4 miles square, which will include a few sections of forest-reserve land in the vicinity of Slim Buttes.

"The preserve is located in the eastern part of Harding County and is 84 miles from the closest railroad point by present highways. This, of course, makes the undertaking rather expensive; but it is a splendid location, even though somewhat isolated."

In connection with the establishment of the State antelope refuge in South Dakota, mentioned above, the following letter, dated December 4, 1923, from State Game Warden Hedrick, is worth quoting:

"Senator Norbeck and myself have been making a personal investigation along this line, having recently put in several days in Harding County, in the northwest corner of South Dakota, investigating conditions and looking for a location for the establishment of an antelope preserve, which was authorized by the South Dakota Game and Fish Commission during the time that Senator Norbeck was governor of the State.

"When the Senator arrives at Washington he will doubtless see you personally and paint a word picture to you of this beautiful prairie animal, as he certainly got very enthusiastic when we came upon a band of 85 head on a fine Sunday afternoon and were within 200 feet of a considerable number of these animals at times. Within 3 miles of this place on the same afternoon we came upon another band of 17 and drove up within 8 or 10 rods of them. There was also a band to the west of us that we did not get close to; we do not know how many there were in this band. Upon talking to the neighbors and ranchers in that section, where the antelope seem to have many friends, my estimate would be that there are at least 225 antelope within a range of 4 to 6 townships. There are also many other bands in Harding County, as well as in Perkins, Butte, and Meade Counties. We also have a band of from 50 to 75 head within 50 miles of Pierre, lying to the northwest of us, in the Cheyenne River country. The Senator and I investigated this situation the latter part of July, this year."

Three unsuccessful efforts have been made to stock the large State game park of South Dakota, but in each case the animals died from disease or other causes. The new antelope refuge is in much more suitable country, and there the animals should do well.

On May 29, 1923, Louis Knowles, predatory-animal inspector of the Biological Survey, who furnished most of the information as to the specific distribution of antelope in South Dakota, wrote that he believed antelope have decreased 50 per cent during the year. This has come about through depredations of predatory animals, diseases, illegal shooting, and a shortage of males. Coyotes are reported to kill many antelope. One of the official hunters has been working in the principal antelope ranges, where he has killed many of these predatory animals, thereby relieving the herds from one of their chief dangers.

On June 23, 1923, Mr. Knowles wrote that stockmen and others throughout the country where the surviving antelope occur report a marked decrease in

their numbers during the preceding 12 months. The only exception to this is in Harding County, where an increase was reported for the past two years, this possibly being due to animals having come in from other sections. A number of small bands of antelope have been exterminated in the State within the past few years.

Stanley Phillips, present owner of the Phillips buffalo herd, informed Mr. Knowles that antelope in northern Stanley County were rapidly decreasing. He reported the existence of a good-sized band there two years ago, which has since been hunted with dogs and has been rapidly depleted. It is reported that officers who were searching the premises of an alleged "moonshiner" in Harding County found 11 antelope skins. It is encouraging to learn that the people in the town of Buffalo are organizing a rod-and-gun club largely for the purpose of giving protection to the remaining antelope in the State.

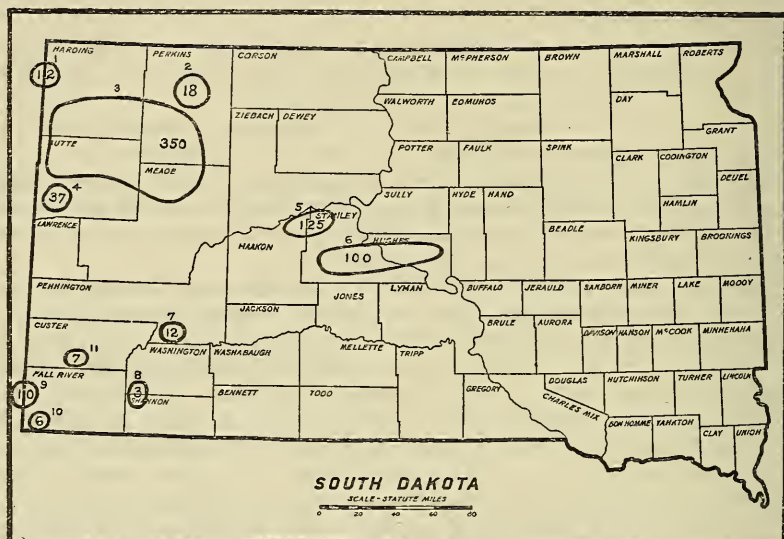


FIG. 15.—Distribution of antelope in South Dakota, estimated at 680, in 11 areas

Mr. Knowles wrote that there has been a disproportionate decrease in the number of buck antelope, and one of the small surviving bands is composed entirely of females. Owing to the scarcity of males throughout the antelope country many of the females do not breed. In one band of 40 only 3 bucks were found.

On June 29, 1923, J. D. Carr, writing from Lindsay, stated that 75 antelope range within a radius of about 8 miles in the Cheyenne Breaks, where they are not being molested. On the same date, from the same locality, F. L. Norman wrote that about 125 antelope are running near Lindsay, where they are so tame that they often come within 100 yards of his home. The crop of young for the season appears to have been large. Mr. Norman states that he and his son try to protect the antelope in every possible way and that they will be pleased to have any measures taken to insure the safety of the herd.

The remaining antelope herds of South Dakota appear to be distributed in the following 11 areas (fig. 15):

1. A band of 12 was reported in June, 1923, in western Harding County, probably ranging across the boundary into Montana.

2. In November, 1923, 18 antelope were reported near Bison, in Perkins County.

3. The largest herds of antelope in the State were reported in 1923 by Senator Norbeck and by the Biological Survey representative, Louis Knowles, as existing in adjacent parts of Harding, Perkins, Butte, and Meade Counties. About 150 animals were reported from around Bam Butte. During this same year O. W. Litzke reported having seen about 300 in a 20-mile ride in the Slim Buttes region. In November, 1923, Senator Norbeck wrote there was a herd of 32 in a pasture 3 miles northwest of Camp Crook, and another small herd of 8 in a pasture near Reva Gap, east from Buffalo. Several scattered small bands occur about the north end of Slim Buttes and several large bands about 15 miles southeast of Buffalo, in the neighborhood of Bam Butte, being some 6 miles west of Slim Buttes. Senator Norbeck added: "I saw two small bunches on a quarter section of land, one of about 40 animals and the other about 45. Several other bands containing from a dozen to two dozen animals each were seen in a couple of miles in different directions from the larger bands. In other words, there must be from 125 to 150 antelope within 5 miles of Bam Butte, which is a small but well-known landmark in the neighborhood." A reasonable estimate of the total number of antelope in this area is 350.

4. Thirty-seven antelope are reported to be living on the Belle Fourche Bird Refuge, in southwestern Butte County, in the Paul Bernard pasture, where they are being protected by the owner.

5. About 125 antelope are reported in northern Stanley and eastern Haakon Counties. Concerning these, Senator Norbeck wrote, under date of July 14, 1924, that he is well pleased with a trip made recently into the Cheyenne River country, and that "careful inquiry among the ranchers who have had a friendly attitude toward the antelope convinced me that there were probably 100 animals ranging over an area 4 miles wide by 10 to 12 long in the breaks on the south side of the Cheyenne River. The distribution seems to be about equal between Stanley and Haakon Counties. It was a surprise to me to find the antelope here, as it did not appear to be choice antelope range, but they have existed here for about 30 years and apparently have held their own."

A band of 30 is probably permanently located on the Carr ranch, in northeastern Haakon County, where there is a pasture about 2 miles wide by 4 miles long, in which the antelope range most of the time, although a year ago last winter they spent several weeks, if not months, on the river flat in an alfalfa field on the ranch. The owner states they did no damage to the alfalfa. Usually they range in the hills and are often seen on high points. Louis Knowles wrote that some appear to be very wild, in part due to the hunting of predatory animals with dogs in this district, during which the dogs frequently pursue the antelope. In addition, there has been a certain amount of hunting with guns. A local hunter agreed that the antelope have not increased here for several years, but during the past three years have about held their own.

6. About 100 antelope were reported in adjacent parts of Stanley and Hughes Counties, where they were decreasing rapidly through being hunted with dogs.

7. Twelve antelope were seen near Scenic, in southeastern Pennington County, in March, 1922, by H. R. Wells.

8. Only 3 antelope, all females, were reported to survive on the Pine Ridge Indian Reservation, in Washington and Shannon Counties.

9. A band of about 10 was reported in 1923 from western Fall River County.

10. In August, 1924, a bunch of 6 antelope was seen 11 miles west of Ardmore, Fall River County. Antelope have supposedly been extinct in this locality for several years, and it is thought this bunch must have drifted in from the west.

11. In October, 1914, 13 young antelope captured near Brooks, Alberta, were placed on Wind Cave Reserve, the gift of the Boone and Crockett Club, of New York City. (See Pl. VI.) Another shipment of 9 animals from the same source was received in October, 1916. The antelope increased very well, but losses were great, caused partly by sickness and partly by attacks of coyotes. Coyotes have been a source of much trouble and in 1918 killed 13 antelope here. Trappers have been sent to the preserve at various times to assist in exterminating these and other predatory animals and have killed

a large number of them. The herd is still more or less in danger, however, from attacks of their predatory enemies. It was reduced to 8 animals in December, 1915; increased to 23 in 1917, and to 34 in 1921; but was again reduced during 1922 and 1923 to 17, and during 1924 to 6 animals, all does. In July, 1924, a young buck, captured in 1923, in northwestern Nevada, was added to the herd, raising the number to 7.

TEXAS

Formerly antelope abounded on the plains of western Texas, but with the occupation of the country they have decreased until it has been possible to obtain definite information of only 42 existing bands, numbering about 2,400 animals, for the entire State. My principal sources of information concerning the antelope in Texas have been W. W. Boyd, State game, fish, and oyster commissioner, and C. R. Landon, in charge of the predatory-animal work of the Biological Survey in that State.

On May 1, 1922, Mr. Boyd wrote that the antelope in Texas were ranging so far as possible in the rougher or sandy lands, owing to their having been hunted in high-powered automobiles. He added that one ranchman in 1922 reported 75 antelope fawns in the herd on his place the preceding year, and that he expected another good fawn crop that spring. Mr. Boyd is taking an active interest in the remaining antelope in the State and believes that the number can be materially increased. In December, 1924, through his deputies and other sources of information he completed the most thorough census of the surviving antelope in the State that has ever been obtained. The number proves to be much greater than was anticipated.

One of Mr. Boyd's deputies, Pete Crawford, writing on January 12, 1925, stated that a small herd of 4 or 5 antelope which ranged a few miles north of Marathon was completely wiped out. Mr. Crawford added that all the antelope herds that he has mentioned particularly in his report are protected by the ranchmen and popular sentiment. He stated that each of the herds that he personally knows is decidedly on the increase, and he believed that at the end of 10 years, if the present program of conservation is carried on, antelope herds in the region west of the Pecos will become a common sight.

In the Houston Chronicle for November 12, 1923, it is stated from Hebronville that—

"Jim Hogg County perhaps can claim the only remaining antelope in southwest Texas. One herd of 16 to 20 ranges near town on the Hellen and Yeager ranches, while the other herd, somewhat larger, is on the W. W. Jones, Wilbur Allen, and Jonas Weil ranches in the southern part of the county.

"While protected by law and the ranchmen, as far as the latter are able to do so, yet occasionally one is killed by a hunter, as they are as gentle as range cattle and easily shot.

"The advent of the farmer in this section also is interfering with these beautiful animals and the time is not far distant when, like the buffalo which once roamed over these prairies, they, too, will have passed."

Apparently the antelope are on the increase in this district, since on January 29, 1925, Mr. Boyd listed herds in that area totaling 285 animals, as indicated in area No. 40 on the map (fig. 16).

H. G. Clark, of Lobo, Tex., writes that coyotes and eagles destroy some of the young fawns, and other causes contribute materially to reduce the increase.

Mr. Landon on April 15, 1922, wrote that 5 or 6 years before he saw between 30 and 40 antelope in one herd ranging near Big Lake, but that last fall the same herd contained only 7 animals. He added:

"There may be 4 or 5 antelope left on the Bar-S Ranch, north of Barnhart, but I am not certain that even this number survives. A few may exist on the 7-D Ranch or adjoining ranches near Stiles, but I doubt if there are at present 30 antelope in Reagan, Crockett, and Upton Counties, where they were formerly in great numbers. A small herd has existed on the Door-Key Ranch, 20 miles south of San Angelo, as long as I can remember, but I now understand there are only two left. These I saw about a year ago.

"On the McIntyre ranch, north of Sterling, there are possibly 20 or 30. Mr. McIntyre protects them as well as he can, but when they get outside of his fence they are usually killed. Sterling and the adjoining counties in all directions except to the east were formerly ideal antelope ranges, but the McIntyre herd is the only one now remaining in that section of the country, and I have been over practically every road in it.

"In the Panhandle a few herds of antelope still remain. On the holdings of the Matador Cattle Co., near Vega, I understand there are two or three small herds. One or more herds are also to be found on the holdings of Lee Bivans, of Amarillo.

"I believe it is conservative to state that where there were 10 antelope in Texas 10 years ago there is now less than one. In the country near Big Lake they suffered the greatest loss one fall three or four years ago, when through an oversight the legal protection of antelope in Texas was allowed to lapse for about 30 days. During this open season they were run down by men in motor cars and hunted so closely that the herd was practically exterminated. On the ranches near Amarillo, which were mainly posted, antelope would probably have held their own so far as human agencies were concerned, but the extremely severe winter of 1918, when the snow remained on the ground for weeks at a time, killed them by hundreds, and only a handful survive."

In a letter dated June 17, 1923, Charles Goodnight wrote that at one time he captured 5 antelope and placed them in one of his fenced pastures near Goodnight, where they increased to 18, after which all were killed by hunters. He added that in his opinion antelope will not live in small inclosures but do well where they have plenty of room.

In the following summary of existing antelope in Texas all the reports are as of December, 1924, unless otherwise stated (fig. 16):

1. Band of 6 reported in Hansford County.
2. Band of 3 reported in Ochiltree County.
3. In 1922, 25 antelope were located on the Sheldon range in Oldham and Hartley Counties, and a band of 4 on the Bivins ranch, near Channing, Hartley County. In December, 1924, the State game department estimated 350 for the entire county.
4. In 1923 there was a band of 5 in the breaks of Moore County; these are now estimated to number 25.
5. A band of 16 is reported from Hutchinson County, apparently about maintaining its numbers.
6. Forty were reported in 1924 in Roberts County.
7. In 1922 a band of 7 were living on the Landergin West ranch, near Adrian, Oldham County; in December, 1924, 125 antelope were estimated to exist in this county.
8. In 1922 60 were reported in the Brown and Trujillo pastures, near Amarillo, Potter County; in December, 1924, only 20 were estimated to be found in this county.
9. Twenty-five are estimated to be living in Carson County.
10. Deaf Smith County is estimated to contain 100 antelope.
11. A band of 10 is reported in Randall County.
12. Fifteen were reported in Castro County in 1924.
13. In 1922 a band of 15 was reported on the Francis Miller ranch in Bailey County; in 1924 a total of 50 was estimated in this county.

14. A band of 9 was reported in 1923 on Spring Lake ranch, Lamb County; in December, 1924, 30 were estimated in this county.

15. One hundred antelope were estimated in the fall of 1924 in Cochran County.

16. Seventy-five are reported in Hockley County.

17. A band of 10 is reported in Lubbock County.

18. Five antelope are reported in Kent County.

19. In the spring of 1924 a band of 5 was reported about 18 miles west of Seminole, and another band of the same number about 16 miles west of Seagraves, Gaines County; in the fall of that year the total number in the county was estimated at 30.

20. A band of five is reported in Borden County.

21. A band of five is reported in Scurry County.

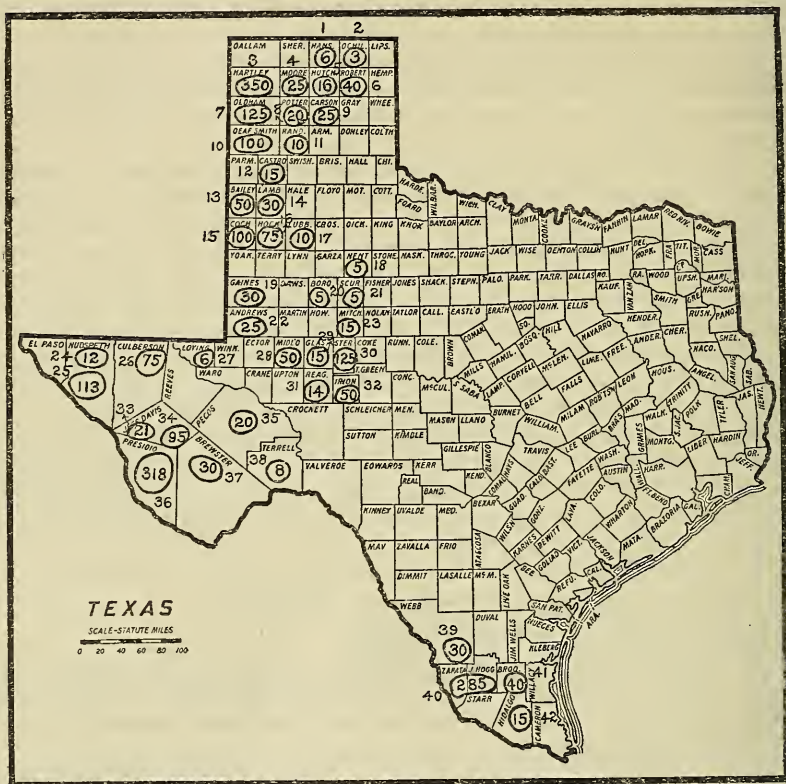


FIG. 16.—Distribution of antelope in Texas, estimated at 2,407, in 43 areas

22. Twenty-five are reported in Andrews County.

23. Fifteen are reported in Mitchell County.

24. In 1922, 10 to 12 were reported as ranging in northern Hudspeth County, southwest of Orange, N. Mex.

25. Several small bands, aggregating about 65 antelope, were reported in 1922 as occurring in central Hudspeth County. A. E. Gray, in charge of the rodent work of the Biological Survey in Texas, writes that the consensus of opinion among ranchmen is that these animals are gradually decreasing. The stockmen state that, in addition to the antelope killed by local residents, numbers are killed by hunters from El Paso who make annual trips into that country during the deer season. In the fall of 1924, however, the State game department estimated a total of 125 antelope in Hudspeth County; in the absence of details as to their distribution it may be assumed that this indicates an increase in herd No. 25.

26. In 1922, 75 were reported on the W. D. Casey ranch in northeastern Culberson County.

27. A band of six was reported in Loving County in 1924.

28. Fifty were reported in Midland County in 1922, but the present status of the band is not known.

29. Fifteen antelope were reported in Glasscock County in 1924.

30. In 1922 about 30 were living on the McIntyre ranch, north of Sterling; in the fall of 1924, 125 were estimated in Sterling County.

31. A band of 7 was reported in 1923 near Big Lake, Reagan County; in the fall of 1924, 14 were reported in this county—probably the same band.

32. Fifty were reported in 1924 in Irion County.

33. In 1922, 13 antelope were reported six miles north of Valentine, and 8 on the Jones Ranch, in northwestern Jeff Davis County; no later report concerning these has been received. In 1924 reports give 21 in the western part of the county.

34. A herd of 20 was reported in January, 1925, ranging on a ranch five miles southwest of Fort Davis. About 75 head were reported also, scattered in small herds, on the H. L. Kokenot ranch along the border line between Jeff Davis and Brewster Counties.

35. In 1922 several small bands were reported east and south of Fort Stockton, Pecos County, and in 1924 about 20 antelope were reported in this area.

36. About 300 antelope were reported in 1924 to be living on the Fisher ranch, 17 miles southwest of Marfa, in Presidio County; these animals are rigidly protected by the owner. On the Cardwell ranch, seven miles west of Marfa, there is a herd of about 18 head.

37. A herd of about 25 is located about three miles northeast of Alpine, Brewster County, in one of H. K. Kokenot's pastures, the animals being carefully protected by the owner. A band of four or five ranges near Altuda in the same county.

38. A band of eight antelope is known to range between Dryden, Terrell County, and the Rio Grande, the band having increased from three animals in 1922.

39. Thirty antelope were reported in the fall of 1924 in Webb County, but the exact locality was not stated.

40. In January, 1925, State Deputy Game Warden O. R. Stephens reported several bands, aggregating about 285 antelope, as ranging mainly in Jim Hogg and Zapata Counties, as follows:

"On the W. H. Yager ranch, situated in the corners of Jim Hogg and Webb Counties, there is a band of antelope numbering 35 head, 17 of which were counted as fawns the past summer. On the W. W. Jones ranch, located in the eastern part of Jim Hogg County, there is a band of about 150 head, 40 of which were counted as fawns last summer. Another band of 40 lives on the Jonas Wiles ranch in the southeast corner of Jim Hogg County, and another of 60 head on the Wilbur Allen ranch in the south part of Jim Hogg County."

41. Forty antelope are reported from Brooks County.

42. Fifteen are reported by the State game department from Hildago County.

UTAH

Antelope were once plentiful and widely distributed over the greater part of Utah. Gradually they have been reduced in numbers until now we have been able to learn of survivors existing in 10 sections of the State, numbering about 670 animals. The information has been mainly obtained through the efforts of George E. Holman and B. B. Richards, in charge, respectively, of the predatory-animal and rodent-control work of the Biological Survey in the State, with the assistance of D. H. Madsen, State game warden. Owing to the size of the State and to the fact that the surviving animals occur mainly in the sparsely settled districts, it has been exceedingly difficult to gather accurate information as to the exact number of these animals, but it is believed that there are few additional to those here reported. Mr. Madson has expressed interest in the conservation of the antelope, and on December 8, 1923, wrote:

"During the past few months we have interested the Union Pacific Railroad Co., which is at present working out plans for the development of the Zion Park and Bruce Canyon scenic attractions, and which has agreed to give us all the cooperation possible in the protection of the antelope."

The information appears to indicate that the antelope in Utah are rapidly decreasing. Very definite and prompt efforts will be necessary to prevent their complete extermination. It is to be hoped that local game-protective associations and others will make special efforts to safeguard the few widely scattered surviving bands. It is gratifying to note that in certain areas, as on the Escalante Desert, in Iron County, the settlers are interesting themselves in antelope protection. Unfortunately, reports from remote districts indicate that herders make a practice of killing these animals when opportunity offers.

The antelope in Utah are distributed as follows (fig. 17):

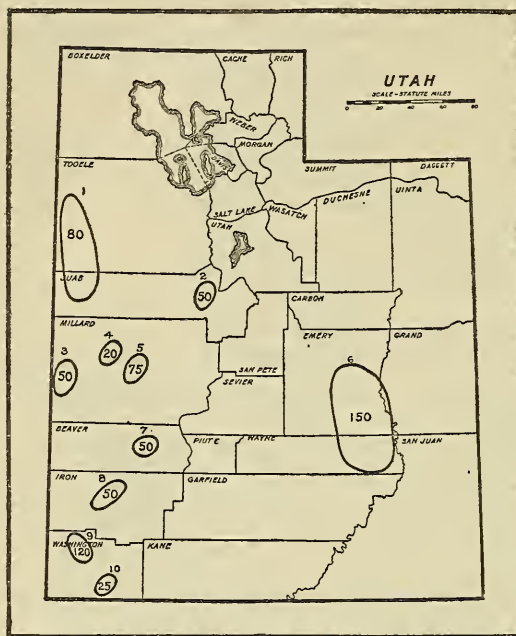


FIG. 17.—Distribution of antelope in Utah, estimated at 670, in 10 areas

1. In 1922 a band of about 50 was ranging in the vicinity of Erickson, in Tooele County, where they were reported as being killed, especially in winter, and in danger of extermination. Another band of 30 was ranging from Callao, in Juab County, to Gold Hill, in the same county.

2. A band of 50 was reported in 1922 as ranging in the vicinity of Cherry Creek, in Juab County, where they were said to be maintaining their numbers.

3. In 1922 a band of 50 was reported in Snake Valley, Millard County. These are the survivors of the herd of about 200 there in 1919. Their decrease is attributed both to their being hunted and to the inroads of predatory animals.

4. In 1922 a band of about 20 was reported in White Valley, Millard County.

5. In 1923 a band of not less than 75 was reported in the vicinity of Sevier Lake, in Millard County. This is said to be increasing.

6. Several bands aggregating about 150 animals were living in 1923 on the desert in Emery and Wayne Counties, ranging thence down to the Green River breaks. A few were reported on the east side of the Green River, in Grand County.

7. In 1922 about 50 were reported in the vicinity of Milford, in eastern Beaver County.

8. About 50 antelope are reported to live on the desert between Lund and Cedar City, in Iron County. Travelers on the road between these two places not uncommonly see some of these animals. As many as 50 have been seen on one trip. The settlers are interested in their protection and the antelope have become very tame. L. L. Carter, who has been long familiar with that region, states that in 1919 there were about 250 antelope there. After a period of heavy decrease it is believed that under the present protection they are now increasing.

9. About 100 antelope were reported in 1922 as about maintaining their numbers in Hamblin Valley, northwestern Washington County. Another band of 20 is reported from Pine Valley, in the same county, concerning which

Mr. Carter states that predatory animals and shooting have caused a reduction from about 50 present in 1919.

10. In 1922 a band of 25 was reported in Hurricane Valley, Washington County.

WYOMING

Wyoming has the distinction of possessing the largest number of antelope surviving in any State. This, however, is only a pitiful remnant of the vast numbers which once roamed its great open plains. Antelope are now reported from 27 sections and total 7,000. In 1885 on the Big Sandy River they were estimated to number about 30,000, or as many as now survive on the whole continent.

Practically throughout the United States, as in Canada and Mexico, there is now a close season on antelope. A modified exception to this rule exists in Wyoming, where an act approved February 18, 1921, which still remains in force, reads as follows:

"Whenever, in the judgment of the State game and fish commission it is deemed desirable, the said commission may direct the State game and fish commissioner to issue not to exceed one hundred special buck antelope permits."

Owing to the numbers of antelope in some sections of Wyoming in 1922, plans were made for the issuance of 100 buck-antelope licenses under this law, but so strong was the public opposition which developed that the idea was abandoned.

The history of the Greybull River herd on the Pitchfork Ranch and vicinity, above Meeteetse, is a good illustration of the manner in which an antelope herd may be built up and also demonstrates the fact that a great increase of game under protection in the midst of a cultivated district may become detrimental to the interests of the farmers and lead to open antagonism toward the animals. The late L. J. Phelps, one of Wyoming's pioneers, living at Meeteetse, many years ago realized that the antelope were disappearing. In 1902 he declared that no antelope should be molested anywhere on his holdings and prohibited shooting. At that time there was a band of about 15 ranging in the vicinity of the Pitchfork Ranch. Through Mr. Phelps's influence during the next 21 years the original 15 increased to about 1,500. During 1923, Charles J. Bayer, in charge of the predatory-animal work of the Biological Survey in Wyoming, visited the Pitchfork Ranch to investigate this herd, and reported that there were practically 1,000 antelope ranging within the boundaries of the territory of area No. 3 on the accompanying map (fig. 18). They were broken into bands of from 25 to 125 each. It is planned to verify the numbers by a count during the fall of 1925. Eugene Phelps, in charge of the Pitchfork Ranch holdings, reports to Mr. Bayer that during the past two years the animals have increased to such an extent that they have become a pest. They enter grainfields after harvest and consume much grain before it can be hauled in and threshed; they also graze throughout the year on lands owned and leased by his company. He contends that the antelope consume sufficient forage from their holdings to accommodate easily a good-sized band of sheep, and this contention appears to be correct. Many of the antelope were grazing in the pastures and fields at the time of this investigation.

A. M. Hogg, representing the Hogg brothers' land holdings in that vicinity, reports that their company has suffered considerable loss of forage through the antelope. He states that during the past four years the antelope have cleaned all the forage from one field of 160 acres. Immediately after a heavy snowstorm on October 24, 1923, a band of between 500 and 700 crossed the fence into an alfalfa and grain field and consumed about half the second crop of forage. They also visited the grainfields at night and destroyed some

grain and ate hay in unfenced stacks but without much damage. With the melting of the snow and the return of favorable weather three weeks later, the antelope left the ranches for the outside range.

It is reliably reported that after a heavy snowstorm in October, 1922, about 500 antelope drifted out of the Meeteetse Valley into the farming country around Burlington, where the farmers shot large numbers, keeping the band moving in an easterly direction until they crossed the Big Horn River. It is impossible to learn how many animals were killed before they crossed the river, but everything indicates that at least half of the band was hung up in meat houses along the way. As near as can be ascertained the survivors did not return.

Eugene Phelps, A. M. Hogg, and Forest Supervisor Andrew Hutton suggest that a limited-license system should permit killing 50 to 100 buck antelope for each of the next two years, in this way ridding the range of many old animals. According to their statement there are twice the number of bucks really needed for the welfare of the herds, and this recommendation was made with the belief that such killing would cause large bands to split and spread into the adjoining areas, thus avoiding their congestion in one central district. If after a couple of years it should be found that the antelope have been properly distributed and are not in sufficient numbers to cause material damage to crops, then the season could be closed again.

The census of antelope in Wyoming has been compiled mainly by Albert M. Day and Charles J. Bayer, of the Biological Survey, with the cooperation of Frank S. Smith, State game warden.

The distribution of the antelope in the State is approximately as follows (fig. 18):

1. The Yellowstone Park herd comprises the antelope which in summer frequent the plains of the upper Yellowstone River, within the boundaries of the Yellowstone Park. During severe winters, particularly when the snowfall is heavy, they have generally been forced to descend along the valley of the Yellowstone River to lower country in Montana. In 1909 the Yellowstone Park antelope herds were estimated to number about 2,000 animals. The last heavy loss occurred in the winter of 1921-22, when the deep snow made it difficult for them to escape the depredations of coyotes and wolves, and others perished from starvation. In the spring of 1922 only 235 remained. Horace M. Albright, superintendent of the Yellowstone National Park, to whom the writer is indebted for the information concerning this herd, in a letter dated September 10, 1924, stated that during the summer of 1923 approximately 70 fawns were born, of which all but 5 survived the following winter. In the spring of 1924 there were approximately 320 antelope in the herd. Reports from the summer range indicate that a large number of fawns were born, and in December, 1924, Mr. Albright reported 410 antelope in the park herd. He arranged to feed and safeguard the animals during the winter of 1924-25. The decrease in numbers in this herd through a series of years appears to have been brought to an end under Mr. Albright's guardianship.

2. In this area about 80 antelope range along the Shoshone River, in Park County.

3. One of the largest single herds in the State is reported ranging on the Greybull River, in southern Park County. It is estimated to contain approximately 1,000 animals and to be increasing. Further details concerning these are given above.

4. There are about 100 antelope southwest of Burlington, in Big Horn County.

5. Bands estimated to number 200 range in the Stagner and Black Mountains and on Owl Creek, Hot Springs County.

6. About 150 antelope are located near Kaycee, in Johnson County, where they are said to be decreasing rapidly.

7. A band of about 60 is reported on Wattel and Hanging Woman Creeks, in northeastern Sheridan County.

8. About 130 are reported about 7 miles southwest of Gillette, in Campbell County. These are said to be fast decreasing as a result of hunting.

9. In this area approximately 350 antelope range on the Belle Fourche River, in Campbell County. Their numbers are reported to be rapidly decreasing through shooting.

10. About 60 antelope are reported along the Little Missouri River and the North Fork of the Cheyenne, in Crook County. These animals undoubtedly range back and forth across the border into Montana. They are reported to be rapidly decreasing.

11. One hundred and fifty antelope are reported to range on Lodge Pole, Prairie Dog, and Black Thunder Creeks and Cheyenne River in Weston County.

12. About 300 range along Antelope, Bear, and Sand Creeks, in northern Converse County.

13. Three bands, totaling about 70, appear to be generally scattered over the northern half of Niobrara County.

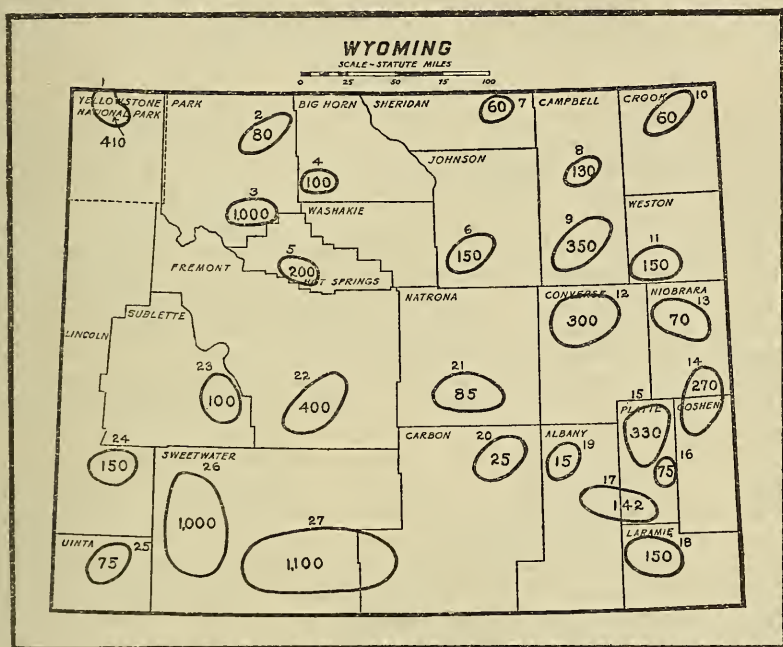


FIG. 18.—Distribution of antelope in Wyoming, estimated at 6,977, in 27 areas

14. In southern Niobrara County is a band numbering about 180, and there are 90 near Raw Hide Butte, in northern Goshute County. These herds appear to be about holding their own.

15. This area, covering part of northern Platte County, is reported to have about 330 antelope, in two bands of 150 each, ranging on Glendo and Flat Top Creeks and Laramie River, and one band of 30 on Fish Creek.

16. This area, in middle eastern Platte County, is reported to have about 75 antelope, mainly about Goshute Hole and Deer Creek, near Wheatland.

17. In the middle eastern part of Albany and southern Platte Counties there are about 142 antelope, made up of three bands, numbering, respectively, 12, 45, and 85, ranging on Sibylee, Antelope, and North Chugwater Creeks. These are reported to be decreasing as the result of shooting.

18. About 150 antelope are reported as ranging on Horse and Bear Creeks, in Laramie County. These are said to be decreasing rapidly.

19. A band of 15 lives on Mule Creek in northern Albany County near Marshall.

20. About 25 are reported in Shirley Basin, in northeastern Carbon County.
21. A band of 85 is reported in Natrona County, along Powder River and Bates, Poison Spider, and Fish Creeks.
22. This area contains about 400 antelope ranging on the Sweetwater Divide, in Fremont County.
23. One hundred antelope are reported on Big Sandy Creek and New Fork of Green River, in Sublette County.
24. About 150 are reported near Fontenelle, in Lincoln County. They are said to be decreasing rapidly through shooting.
25. About 75 occur on Muddy Creek, in Uinta County, where they are said to be rapidly decreasing.
26. In the Green River Valley, in western Sweetwater County, about 1,000 antelope are reported, which makes it the second largest herd, and gives Sweetwater County a total of 2,100 antelope (see area No. 27), by far the largest number surviving in any county in the State.
27. This area is reported to include about 1,100 antelope, the largest number in any similar area in the State. It lies mainly in southeastern Sweetwater County, extending into the adjoining part of Carbon County. The main bands range on Black Rock, Shell, Skull, and Lost Creeks.

CANADA

In Canada antelope are now limited to the Provinces of Alberta and Saskatchewan. In Alberta bands are located in 5 areas, containing a total of about 1,030 animals. In Saskatchewan they are located in 9 areas in which are about 297 animals, or a total of 1,327 north of the United States. Antelope formerly ranged east into Manitoba and north to the limit of the plains along the Saskatchewan River. For some years the antelope in Canada diminished rapidly, but are reported now to be about maintaining their numbers or even increasing in some areas. Although the conservation of antelope in Canada is mainly a matter for the attention of the Provinces, yet the Dominion Government assumes general responsibility in regard to all wild life, particularly concerning the antelope. The Canadian National Park at Nemiskam was especially created for their protection. J. B. Harkin, commissioner of Canadian national parks, states:

"The question of creating other parks as sanctuaries is now receiving the attention of the department. Our efforts are being retarded, however, owing to lack of appropriations necessary to proceed with the work. A limited number of young antelope are being raised on the national antelope refuge at Nemiskam and will be transferred to Buffalo National Park at Wainwright, Alberta, as soon as they are old enough to be shipped. These, with the antelope already at the park, will form the nucleus of a new herd. I think it can be safely said that, due to the efforts put forth in recent years for the protection of these animals, they have not seriously decreased and are now holding their own."

Concerning the heavy losses of antelope which were reported to have taken place by their drifting against fences along the railroad in this region some years ago, F. Bradshaw, game commissioner of Saskatchewan, writes that no serious recent losses of this kind have occurred, but that he read an article not long ago by Doctor Prince in *Rod and Gun* in Canada, in which reference was made to thousands of animals dying along the fence of the Canadian Pacific Railway west of Swift Current.

For the information concerning the surviving antelope in Canada the writer is indebted to J. B. Harkin, commissioner of Canadian national parks; to F. Bradshaw, game commissioner of Saskatchewan; and to Benjamin Lawton, chief game warden of Alberta.

The distribution of the herds is as follows (fig. 19):

ALBERTA

1. About 500 are reported on the north side of Bow River above its junction with Lethbridge or Belly River, west and south of Brooks, on the Canadian Pacific Railroad.

2. About 100 range on Red Deer and South Saskatchewan Rivers, a short distance west of their junction.

3. About 100 are reported in the section between Belly River and Bow River, to the northeast of Lethbridge.

4. On the National Antelope Refuge in Nemiskam, to the west of Lake Pakowski, 180 antelope were reported in September, 1924.

5. The latest information, in 1924, gives about 150 as ranging in the extreme southeastern corner of the Province.

SASKATCHEWAN

6. About 40 antelope are said to range on both sides of the South Saskatchewan River, west of Owensville.

7. To the northeast of White Bear Lake about 20 antelope are said to range.

8. A band of 8 antelope is reported on the South Saskatchewan River a few miles west of Saskatchewan Landing.

9. Between White Bear and Luck Lakes, some distance north of the South Saskatchewan, 12 antelope are reported.

10. A band of about 10 are reported near Long Valley, northwest of Lake Chaplin.

11. About 100 range about Bigstick Lake, north of Maple Creek on the Canadian Pacific Railroad.

12. To the north of Cypress Lake, in the southwestern corner of the Province, 40 antelope are reported.

13. On the north side of Frenchman Creek, near the town of East End, 27 are reported.

14. About 40 are reported to occur in the area south of Wood Mountain, drained by Frenchman Creek and Poplar River, both tributary to the Missouri.

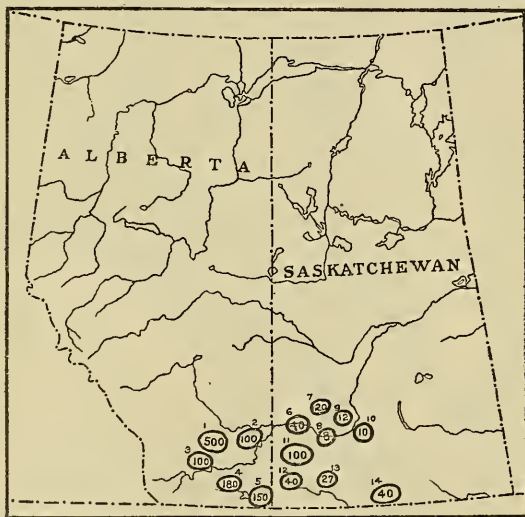


FIG. 19.—Distribution of antelope in Canada, estimated at 1,030 in 5 areas in Alberta, and 297 in 9 areas in Saskatchewan; a total of 1,327 in 14 areas

MEXICO

It has not been possible to obtain definite information concerning the distribution of the antelope bands or the numbers contained in them from any part of Mexico except Sonora. The accompanying maps (figs. 20 and 21) and statements concerning the surviving antelope in that country are based on personal knowledge of the writer and on information mainly received from Carlos Lopez, in charge of the Federal game administration of Mexico, and from Game Warden Ben Tinker.

Formerly antelope ranged south over the great Mexican tableland to within less than 100 miles of the City of Mexico. It is interesting to know, as set forth earlier in this report, that the first mention of antelope seen by Europeans

on this continent was recorded in an account of a great hunt organized for the viceroy of Mexico in 1540, at a point near the present station of Cazadero on the Mexican Central Railroad in extreme southwestern Hidalgo.

The main herds of antelope in Mexico are undoubtedly located on the broad arid plains of Coahuila, Chihuahua, and northeastern Durango. Other herds occupy considerable territory in northwestern Sonora, some occasionally ranging back and forth across the border between Sonora and Arizona, and others are located in Lower California. From information received it appears possible at this time that, in general, antelope may be holding their own in Mexico.

On October 1, 1922, a close season of 10 years on antelope, which had been established by President Obregon, became effective. This should serve to lessen the number of these animals killed and so favor their increase. There

are great areas of sparsely occupied plains on the northern Mexican tablelands where they might find a home far into the distant future.

To assist in safeguarding the antelope and other game animals of northern Sonora the Permanent Wild Life Protection Fund, through Doctor Hornaday, has entered into an agreement with the Mexican Government whereby it employs Ben Tinker as game warden, with headquarters at Tucson, Ariz., to work along both sides of the Arizona-Sonora border to prevent poaching.

It is conservatively estimated that there are 2,395 antelope in Mexico, of

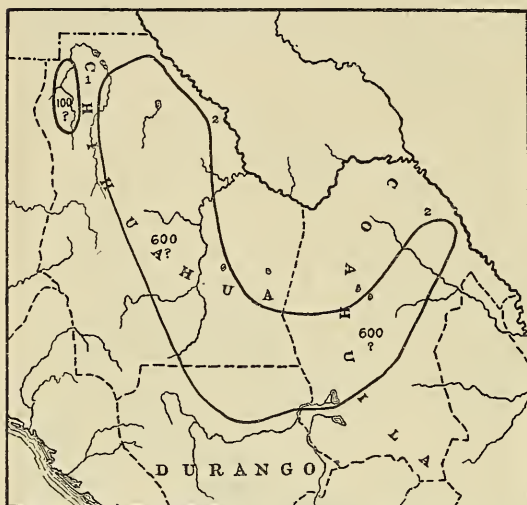


FIG. 20.—Distribution of antelope in parts of Mexico—in Chihuahua, Coahuila, and Durango, estimated at about 1,300 in 2 areas (see also fig. 21)

which 1,300 are estimated to be in Chihuahua, Durango, and Coahuila, and 500 in Lower California. The remainder are more definitely known in Sonora. These numbers will serve as a working basis until there is opportunity to get more complete information. It is probable that there may be many more on the plains of Chihuahua and Coahuila than here estimated. The following details of distribution are based on a letter received from Professor Lopez in January, 1924, and from other information available on the subject. It is grouped under States and the Territory of Lower California, as follows (figs. 20 and 21) :

COAHUILA

In the great Valley of La Encantada, to the west of Muzquiz, bands of 50 to 100 antelope occur. They are also about the Hacienda de San Antonio, and are more abundant about the Hacienda de Paila and on the plains about the neighboring mountain range of Espianzo. Most of the antelope in Coahuila are located west of the railroad which runs south from Eagle Pass, Tex., to Saltillo, and north of the railroad extending from the last-named place westward to Torreon.

CHIHUAHUA

In extreme northwestern, southeastern, and eastern Chihuahua antelope occur in varied numbers. The bands in the extreme northwestern part are separated from those which range along the Mexican Central Railroad to the east. The great Bolson de Mapimi and the region east of the Mexican Central Railroad is a vast territory ideally suited to the needs of these animals. In southern Chihuahua antelope occur on both sides of the Mexican Central Railroad, particularly along the border of Durango.

DURANGO

In Durango antelope are now limited mainly to the northeastern part of the State, in the district of San Dimas. Antelope are reported to be rather common in the following localities: Lapioriz, Maravillas, El Pilar, Santa Rita, San Julián, Las Lagunas, Huachinapas, San Francisco de los Lobos, Pericos, and Huahiapa y Gavilanes. They are also said to be abundant in the district about Escalon, along the border of Chihuahua and Durango, near the base of the Sierra del Diablo.

SONORA

Antelope in Sonora are practically all west of the railroad extending from Nogales on the Arizona border south to Guaymas and in the region lying north of a line drawn from Hermosillo west to the coast of the Gulf of California. A few bands in northwestern Sonora

range back and forth across the Arizona border. It is these bands which are now under the guardianship of the Permanent Wild Life Protection Fund.

Under date of January 4, 1925, Ben Tinker, who represents the Permanent Wild Life Protection Fund along the Sonora-Arizona border, supplied the writer with interesting information concerning the distribution of the surviving antelope in Sonora. They are reported to occupy 4 areas and to have totaled 595 animals in November, 1924, when they were counted by him. Following is his summary of these antelope herds:

1. Comprises numerous bands, numbering 459 all told, ranging from the southern end of the Sierra Rosario south and east to the Sierra Blanca and the Rio Sonoyta, thence eastward (north of Sierra Pinta) to the eastern side of the Sierra de San Francisco. The largest single band, containing 73 animals, ranges between the Sonoyta River and Sierra de San Francisco during the months of October, November, and December and southward from this river to the Sierra Pinta during the remainder of the year.



FIG. 21.—Distribution of antelope in Lower California and Sonora, Mexico, estimated at 500 in 2 areas of Lower California, and 595 in 4 areas of Sonora; a total of 1,095 in 6 areas (see also fig. 20)

2. Comprises 17 in two bands between the Sierra de la Nariz and the town of Altar.

3. Comprises 56 in small, scattered bands from Sierra del Cajon eastward to within six miles of Noria Station on the S. P. de M. Railway.

4. Comprises 63 in many small bands between the Rio San Ignacio and the city of Hermosillo.

LOWER CALIFORNIA

Antelope in Lower California are distributed mainly on the plains east of the central mountain range from the California border south to the middle of the peninsula. They are also on the desert of Vizcaino, where they live west of the main mountain range, reaching the borders of the Pacific on the shores of Vizcaino Bay on the north and Ballenas Bay on the south. It is estimated that not less than 500 antelope survive on the peninsula. Formerly antelope in Lower California ranged south beyond Magdalena Bay, but for many years they have been extinct over a large part of their former territory. During the past 15 years antelope have been continuously hunted in Lower California, and it is rather surprising that they have continued to survive. It is hoped that the operation of the present close season on them may result in their numbers again increasing. Natural conditions are such that Lower California will never be densely populated or occupied by farming communities of any importance. Water is scarce in the interior, and great plains covered with desert vegetation afford an ideal home for antelope. With reasonable protection they might survive there in large numbers far into the future (fig. 21).

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Washington, D. C.

September, 1925

THE BROOD-REARING CYCLE OF THE HONEYBEE

By

W. J. NOLAN, Associate Apiculturist

Division of Bee Culture Investigations, Bureau of Entomology

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INTRODUCTION

In previous work of the Bureau of Entomology emphasis has been placed on the conditions necessary for the proper wintering of bees, in order that colony population and energy may be conserved to the utmost during the period when no brood is reared by normal colonies. It is evident, however, that merely wintering the bees in the best possible condition will not in itself guarantee that the colony will at the right moment have the proper strength and composition for gathering a maximum honey crop. Nevertheless, if, through proper wintering, the strength of the colony has been adequately conserved, the resumption of brood rearing in the spring may take place at the proper time and the amount of brood reared may increase at a remarkable rate, since the ability of the colony will not have been impaired through excessive work during the winter. It is appropriate, therefore, that the investigation of wintering conditions should be followed by an investigation of the factors which modify brood-rearing activity, more especially those which are under the control of the beekeeper.

Since normally a worker bee, before going to the field, spends the first two or three weeks of its life in duties within the hive, the quantity of nectar gathered by any colony depends not merely on the total number of bees in the colony during a honey flow, but on the number included within that total which represents bees of proper age to serve as nectar gatherers. In order to have the largest possible number of field bees at the proper moment, therefore, the highest daily rate of bees emerging from the brood cells during any given season should

occur about three weeks in advance of the main honey flow; in other words, the queen should reach her maximum daily egg-laying rate during the period six weeks prior to the honey flow. Since in a colony left to itself such is usually not the case, a correct understanding of the principles governing brood rearing throughout the year becomes of prime importance to the beekeeper, if he is to handle his colonies in such a way as to secure a maximum honey crop.

Lack of knowledge of the principles governing brood rearing may cause a reduction in the honey crop by bringing about in a colony any or all of the three following possibilities:

1. The population of the colony may not become large enough to provide sufficient field bees during nectar flows to gather surplus adequate to give the beekeeper a fair return for time spent and capital invested.

2. Surplus honey may be consumed in regions of early nectar flows by bees which have emerged too late to serve as nectar gatherers, and too early to winter over or even to assist in building up the colony for winter.

3. Swarming may be stimulated if the ratio between hive bees and field bees does not remain such as will avoid causing a congestion within the hive whenever one of these classes is relatively idle while the other is extremely busy.

The prevention of any or all of these states involves such questions as wintering, stores for spring, requeening, population of the colony at the beginning of brood rearing, swarm control, dequeening, removal of brood, and other related factors. In short, regardless of its immediate purpose, every sound beekeeping practice having to do with the actual manipulation of the colony itself has as its final result the elimination or prevention of some one of the three above-mentioned conditions. The utility of any manipulation of the colony may well be gauged by the extent to which such an outcome is achieved. It is essential, then, to have a clear understanding of the principles of brood rearing in order to apply the proper procedure to any case so as to obtain the desired result.

The manner of increase in a colony's population has been under discussion since the days of the ancients. Views on this subject prior to the latter part of the seventeenth century, however, differed widely from those now held, since the sex of the queen had not yet been determined and many people even believed in the spontaneous generation or creation of bees. That brood rearing is a phenomenon in which the queen is concerned directly was not generally recognized until Swammerdam (14, p. 159)¹ in 1669 established clearly the actual relationship borne by the queen to any increase in the colony's population. Since this great apicultural discovery, beekeeping literature has been filled with reports and conjectures as to a queen's daily egg-laying capacity, and the total amount of brood reared during a season. Among early investigators in the field, Reaumur (13, p. 475) in 1740 stated that the height of egg laying comes in the spring and that over a period of two months at that time the queen may average 200 eggs per day, this average being accepted for nearly a century afterwards as fairly typical of a queen's egg-laying capacity.

¹ Reference is made by number (italic) to "Literature cited," p. 37.

The first trustworthy determination of the number of eggs laid in a single day was made by von Berlepsch (3, pp. 68-69) in 1856. Having succeeded in confining the egg-laying activity of an especially prolific queen to a single comb for 24 hours, he found that meanwhile 3,021 eggs had been laid. An estimate of the amount of brood remaining in the hive to which the queen belonged led to the assumption that she had been averaging nearly 3,000 eggs daily for the preceding 20 days. During the remainder of the nineteenth century this rate was widely accepted as a proper index of a queen's daily egg-laying capacity, although von Berlepsch himself believed such a rate to be exceptional, and that a daily average of only 1,200 is probably usual. Inasmuch as this particular queen was active for five seasons, von Berlepsch assumed that she must have laid at least 1,300,000 eggs during her lifetime, a number which apparently has served many later writers as a basis for their estimates of the total possible egg-laying achievement of a queen. Baldrige (2), an American contemporary of von Berlepsch, deserves mention because he furnished the first published census of all the eggs, larvæ, and sealed brood in a modern hive, determined by an actual count. He even entertained the idea of counting all the eggs in a certain colony every 72 hours, but apparently never carried it into effect.

The first authentic data as to the total number of eggs laid by a queen throughout an entire season were published by Desborough in 1852 (8). In 1855 (9) he published data in regard to the number of eggs laid by one queen in two successive seasons, and in 1868 (10) he presented similar data covering six successive seasons for a single queen. Desborough's figures were obtained by making periodic estimates of the area occupied by brood. The colony used seems to have been so much below normal strength, however, that his findings can not be taken as typical. For the next 40 years, of the many reports on the quantity of brood found in a hive, or of the daily egg-laying capacity of a queen, few are of any real value in understanding the annual brood-rearing cycle. Interesting as they may be, these reports too often represent only the performance of some exceptional queen during a single day at the height of the season. Such sporadic endeavors, either in themselves or in relation to other similar reports from localities under far different conditions, afford little basis for drawing conclusions as to brood-rearing activity throughout a whole season. Although during this long stretch of years it may have been realized that the annual brood-rearing cycle can be determined only by continuous observations on the same colonies during any given season, apparently no one undertook the task. Finally, in 1895, Baldensperger (1) furnished the first published results of successive counts or estimates throughout the year of the quantity of brood in a colony of normal strength.

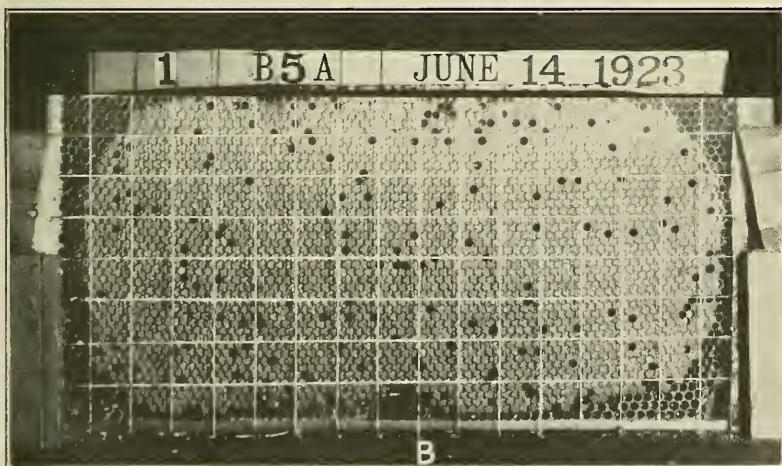
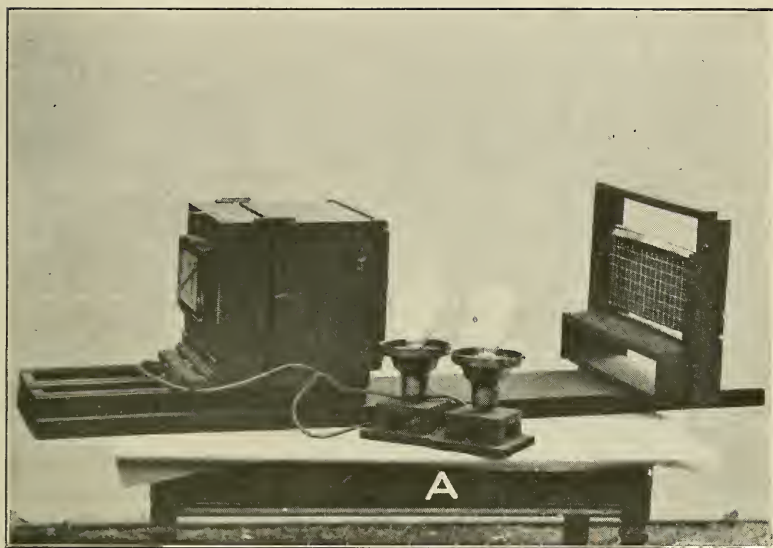
An epoch in this line of research is marked in 1901, when Dufour (11) published data obtained from the first comprehensive study of the subject by a scientific method of approach. As a result of four years' work he had secured seven seasonal brood-rearing records by actually counting, at intervals of approximately 21 days throughout each season, every egg, larva, and sealed brood cell in each colony used. In 1912, the first seasonal curves based on results from brood-rearing investigations were presented by Brünich (4). In 1919 (5), and again in 1922 (6), he presented other

similar curves, representing the daily egg-laying rate of various individual queens. Brünnich's work, unlike Dufour's, is based, not on an actual count of each cell containing brood, but on a mathematical calculation of the number of such cells derived from linear measurements of the brood area on each frame throughout the season. From data thus obtained daily egg-laying rates are calculated for the whole season. Although the claim can not be made that Brünnich's work is as nearly accurate as Dufour's, the Swiss investigator has adopted a method which is fairly speedy and readily utilized, and which gives results reliable enough for most purposes.

METHOD

In 1920 work on this problem at the Bee Culture Laboratory was first begun when Lloyd R. Watson, formerly apicultural assistant, made actual counts weekly of all eggs, larvæ, and sealed brood in five colonies for the entire season. Any such method of counting brood on each comb is necessarily slow. In cool weather it involves the possibility of brood becoming chilled before the operation is completed; at other times there is danger of robbing, and in any event there is too long a disturbance of the colony. Accordingly, when the writer took over the work at the beginning of the season of 1921, a photographic method was determined upon, whereby photographs are taken weekly of every frame containing sealed brood, and counts are made later from the negatives. Only sealed brood is counted, because of its greater clearness on the negatives. As a result of the use of this method, photographic records of 16 colonies were obtained in 1921, and of 32 colonies in 1922. Adding to these the counts from the five colonies in 1920, the equivalent of a total of 53 individual seasonal brood-rearing records has been obtained already from the work now in progress.

A small building adjacent to the apiary not only houses the camera permanently but also affords protection from robber bees while taking the pictures. During exposures two 500-watt electric lamps furnish light sufficient to obtain good negatives at all times within the building, regardless of conditions of light outdoors. The camera itself is fastened securely to one end of a base made of 2-inch plank. To maintain the brood frames firmly in position during exposures and yet to have in the negative an image of every cell on the exposed side of each comb, a substantial holder (Plate I, A) is used which consists of a base with two uprights at each end, the uprights being joined by a top piece. The width of the holder is such that the lower half of each end bar of a Langstroth frame just fits into a groove extending upward from the base on the inner surface of each upright. A super spring fastened to the rear edge of each groove presses the end bar firmly against the front edge, and thus the brood frame is held rigidly in a definite position, although it may easily be slipped in and out of the holder. The holder itself is fastened securely to the same base as is the camera, but at such a distance from the lens as to give a reduction to a scale two-thirds that of the original. Because of the uniform focal distance and the uniform illumination, all negatives are made on an identical scale and under the same light conditions. By the aid of a suitable device attached to the frame holder there is photographed with each frame of brood a record showing the date, the hive and hive body from which the frame came,



PHOTOGRAPHIC PRODUCTION OF BROOD RECORDS

A.—Apparatus used in obtaining records, showing camera, brood-frame holder with brood frame in position, wire net, record, and electric lamps. B.—Print made from a photographic record, illustrating the character of a permanent record

the location of the frame in the hive body, and the particular side of the frame. A net of wires forming 1-inch squares is permanently fixed to the holder at such a point as barely to clear the surface of any brood frame in the holder and still be in focus. The squares, showing clearly in the negative (Plate I, B), divide the brood area into such small sections as to render possible an extremely accurate, direct count.

For recording the counts from each negative, a card is ruled into squares identical in size and number with those in the picture itself. All squares corresponding to areas containing only sealed worker cells may be credited with the number of cells contained in 1 square inch; but in squares containing unsealed as well as sealed cells, the number of unsealed cells must be deducted first. There are many contradictory statements as to the number of cells per square inch, due in part to attempts to derive it mathematically from the dimensions of some single cell instead of counting the actual numbers in areas large enough to get a trustworthy average. Watson, by making such counts, found the average number per square inch to be slightly in excess of 26. This number has been used in the results presented here. Some variation exists between individual combs, however, possibly due to the foundation used. Thus, in combs from certain foundation the writer has found 26.3 worker cells per inch, and in combs from foundation bought after the results for 1921 were obtained he has found approximately 27 worker cells per square inch. Much of this latter type of foundation has been used since that date, and subsequent results are therefore being calculated on this basis. It is very evident that the general relations of a curve based on the amount of brood counted will remain the same, regardless of whether in the counts the number of cells per square inch is taken to be 26, 27, or some other figure of nearly the same size. As a matter of fact, the difference between 26 and 27 is less than 4 per cent, or less than 40 in every 1,000.

In areas containing 50 per cent or more of unsealed cells it has been found preferable to count each individual sealed cell. Sealed drone cells also are counted individually. They have little influence on the totals, however, because by proper selection of brood combs it has been possible to keep the total of sealed drone cells well below 600 on any one count. Since in counting individual cells, either sealed or unsealed, some arbitrary rule must be followed in crediting them to a particular square; all such cells are credited to, or deducted from, the total of the square immediately to the left of the vertical dividing line, or below the horizontal dividing line, as the case may be. Totals for each card and colony are calculated on an adding machine. The photographic record once obtained, the actual counting may be delayed until any convenient time, so long as the negative does not deteriorate. A series of such records permits making a year-by-year comparison of any portion of the sealed-brood area. Cut films, 5 by 7 inches in size, are used exclusively in this work.

Before photographing, all of the frames containing sealed brood in any given hive body are shaken or brushed free of adhering bees, placed in an empty hive body, and immediately carried to the building where the photographs are made. The exposures can be made in 10 seconds, thus keeping the frames out of the hive for an exceedingly short time. Danger of chilling the brood is thus reduced to a

minimum, although in any event, in the cooler weather of spring or fall, there are few frames containing sealed brood. The hive being open for so little time, danger from robbing is also reduced, and the normal activity of the colony is disturbed to a far less degree than is the case in any other method of brood-area determination so far employed. The great speed with which the work can be accomplished adapts this method to investigations on a large scale. In the first two years of this work more than 18,000 pictures were thus taken.

DEFINITIONS

The term "brood nest" as used in this bulletin applies to the space occupied by brood, regardless of the number of hive bodies in which brood is found. The term "brood area" is similarly applied. The term "super" is used for the hive bodies which are placed above the second hive body to give additional room for colony activity, the lower two hive bodies being those which remain with the colony permanently, summer and winter. The hive bodies are of uniform size, regardless of purpose. Brood could be reared in the supers of hives in which no restriction was placed on the movements of the queen by a queen excluder. In the apiary of the Bureau of Entomology, where this work was done, the colonies are arranged in groups of four for convenience in putting them into packing cases for winter, and such groups are referred to as packing-case groups. The term "quadruple packing case" refers, of course, to the fact that each of the packing cases used is capable of containing four colonies. "Nectar flow" and "honey flow" are used synonymously to cover those periods in which nectar available for the honeybee is secreted freely. "Pollen yield" refers to the gathering of pollen in large quantities. The term "natural requeening" is used in this bulletin for the requeening of colonies in which it is impossible to determine whether the old queen was lost through natural supercedure or whether she was accidentally killed while the colony was being handled. Where artificial requeening was practiced, as by the killing of the old queen and the giving of a queen or queen cell, the period of queenlessness is less than in natural requeening.

ANNUAL BROOD-REARING CYCLE

Common recognition of certain factors underlying brood rearing has given rise to different apiary practices. For example, it has long been believed, regardless of geographical conditions, that a honey flow greatly stimulates egg laying. This is attested by such apiary practices as dequeening during a honey flow, removing brood, and the like. Although apiary practice has contributed much to a knowledge of brood rearing, it has not as yet furnished a clear, definite understanding of all of the factors causing an increase or decrease of brood-rearing activity. For instance, it has not been established as a fact that brood-rearing activity increases in a uniform and regular manner during the beginning of the active season, nor that irregularities may then occur. In short, each seasonal phase of brood rearing presents problems, not fully solved as yet, which are of vital importance in beekeeping practice.

It is a matter of common apiary experience that during a certain portion of the year, depending on weather, nectar flows, and other

conductive factors, brood-rearing activity is prevalent, and that in the remaining portion of the year brood-rearing activity is suspended. The annual brood-rearing cycle may therefore be divided into two parts: (1) a period of seasonal activity and (2) a period of seasonal suspension. The period of seasonal brood-rearing activity, or the "active season," takes place, roughly speaking, during the summer; the period of seasonal suspension of brood rearing, here called the "inactive season," occurs in winter.

SEASONAL ACTIVITY

At the end of the inactive season, marked normally by the first incoming nectar or pollen, brood rearing is resumed and may proceed to a certain maximum in the fore part of the active season at a rate which is often strikingly noticeable. Brood-rearing activity during the remainder of the active season, up to the period of final decline, varies widely with geographical location or climatic conditions. In some regions it is maintained at a uniformly high rate throughout; in other regions it is broken in continuity by an interval of partial suspension. In still other regions there is a gradation between these two extreme types of seasonal brood-rearing activity. The final decline is either abrupt or gradual, depending also on geographical location. Regardless of geographical location or climatic conditions, the period of seasonal activity may be divided into the three following phases: (1) A period of initial expansion, (2) a major period, (3) a period of final contraction. It is not always possible to draw a sharp line of demarcation between these three seasonal phases of brood-rearing activity, because external environment, such as weather or incoming nectar and pollen, often causes the end of one seasonal phase to become so merged with the beginning of the next that the initial influence of the succeeding phase can not easily be detected.

PERIOD OF INITIAL EXPANSION

The initial expansion covers that period of the active season immediately following the inactive season, in which brood-rearing activity is normally resumed and is continued in spite of conditions which if occurring later in the season would tend to check brood rearing. It should be pointed out that the beginning of brood rearing here discussed is that caused by the incoming of the first nectar or pollen and does not apply to abnormal brood rearing during the inactive season, which will be discussed later. At no other time in the year does the tendency to rear brood seem so persistent as during this initial phase, except possibly when a colony has just swarmed or when a queen is beginning to lay for the first time. Although the rate of increase in brood-rearing activity may be greatly accelerated during the period of initial seasonal expansion by incoming nectar or pollen, the fact that such an expansion continues after resumption of brood rearing, even with no incoming nectar or pollen, indicates that this phase is purely seasonal and needs only the approach of spring to cause its appearance.

Since this expansion in the spring is a seasonal phenomenon, and is bound to occur, the colony which will gain the most rapidly in population in the spring is the one possessing the largest number of factors favorable for brood rearing. It becomes readily apparent,

then, how important it is for the beekeeper to do everything in his power to have conditions in the hive just right at the moment this phase begins, if his colony is to get a good start from the very beginning of the season. Such action on the part of the beekeeper is especially imperative in regions where the honey flow follows close upon the opening of the active season, because under such circumstances little time is given the colony in which to build up, and such time as is granted must be used to best advantage. In localities with early honey flows a successful season is dependent largely on the number of bees reared in the period of initial expansion.

Regardless of any direct bearing upon the honey crop, it is to the advantage of the beekeeper to make the most of the tendency toward greatly heightened brood-rearing activity during the period of initial expansion, merely for the sake of having his colonies strong enough to resist certain diseases successfully. A colony which has gained a maximum population during the initial expansion is in a far better position to ward off European foul brood than is one which increases only slowly in the spring. It is too often the case in regions where this disease is prevalent that the nectar flows are not so correlated with the period of initial expansion as to result in a strong enough population to enable a colony to overcome the presence of this disease. That strength of population will minimize the effects of diseases of adult bees also is shown by the comparatively slight loss occasioned by *Nosema apis* in strong colonies. Morgenthaler (12) has stated his belief that a good prolific queen is one of the greatest aids in overcoming the Isle of Wight disease. In other words, the colony which successfully withstands the disease must be in good condition and strong enough to discount the loss in the adult population. Among all the invaders of hive or colony itself, the wax moth furnishes probably the most commonly recognized example of the importance and utility of a strong colony population as a curb to the harmful activities of invading organisms. For a colony to be strong throughout an entire season, however, a maximum increase in population must have been made first of all during the initial expansion. The successful beekeeper supplies conditions which cause the largest possible increase of colony population during the initial expansion, not only for the sake of obtaining a large number of honey gatherers during this period, but also to provide sufficient bees to resist chance inroads upon the colony. This especially applies in regions where natural conditions between the period of initial expansion and the main honey flow are not conducive to a sufficient increase in population to keep the colony from falling an easy prey to certain invading organisms.

Among some of the important factors which are within the power of the beekeeper to provide are a prolific queen, sufficient bees wintered over to meet all brood-rearing requirements in the spring, sufficient worker brood cells, sufficient stores of good honey, and proper insulation. All of these are factors which must and can be provided in the manipulations in the latter part of the previous season if the beekeeper wishes to take the utmost advantage of the natural tendency toward intense brood-rearing activity at the beginning of spring. Conditions within the hive making for brood rearing during the period of initial expansion may be likened to a charge of explosives set to go off at a certain moment in the spring, the time

depending on weather conditions; in the one case the force of the resulting explosion is definitely predetermined by the quantity of the charge; in the other case the amount of brood reared is definitely predetermined by the provisions made in the preceding season to give the colony the conditions most favorable for this purpose.

THE MAJOR PERIOD

The major period of brood-rearing activity extends throughout the active season from the time when normally the initial seasonal tendency would cease to make itself felt until the beginning of the period of final contraction. It is the longest of the three phases of seasonal activity. The character and sequence of honey flows under different climatic conditions cause brood-rearing activity during this phase to vary widely in different regions. Throughout the world, on the whole, brood-rearing activity during the major period falls either into one of two extreme types or into a gradation between the two. During this period one of the extreme types is marked by a continuous high rate of brood-rearing activity, while the other extreme type is marked by a pronounced slackening or series of slackenings in such activity. In the third or intermediate type there is neither a continuous high rate of brood-rearing activity during the major period, nor under normal conditions is there at any time a complete suspension. This intermediate type, however, does show a seasonal slackening at some time within the major period.

A continuous high rate of brood-rearing activity during the major period occurs in regions with a long inactive season in winter, followed by a short active season, usually characterized by overlapping honey flows. Following the prolonged period of winter suspension in such a region, brood-rearing activity during the period of initial expansion attains with striking rapidity a high rate, which, unless checked by conditions within the hive, is maintained throughout the major period extending over practically the whole of a relatively short active season and then, owing to the proximity of the period of winter suspension, undergoes an abrupt contraction. Such a type of seasonal brood-rearing activity during the major period is typical of subarctic conditions.

A more or less complete suspension of brood rearing, or series of such suspensions, is found in regions with a short, almost nonexistent, inactive season, followed by a long season of activity, usually characterized by one or more periods of drought during the hottest weather. In such a region the initial expansion in brood rearing does not progress so rapidly as in regions with a long, inactive winter season, nor is the final contraction so abrupt. The major period, instead of being characterized by a uniformly continued high rate of brood-rearing activity, is characterized by a pronounced midsummer slackening, or series of slackenings, in brood-rearing activity, probably caused by an absence of incoming nectar and pollen during the periods of drought. This type of brood-rearing activity during the major period is typical of tropical conditions.

Intermediate between the two types just described is that type of seasonal brood-rearing activity which exhibits a more or less marked slackening at some time during the major period, but never a complete suspension under normal conditions. This type may be found

in the middle and southern latitudes of the United States. Brood-rearing activity after this period of midseason slackening may equal in intensity and extent that which took place before the slackening. An example of this type is found in regions of the southern Appalachian Mountains, where there is an early honey flow from the tulip-tree, followed by a midsummer dearth of nectar, which in turn is succeeded by a later honey flow from sourwood. In other regions where the continuity of brood-rearing activity is broken by a midsummer dearth of nectar brood rearing during that portion of the major period having the larger amount of nectar available is much more active than it is in the other portion. In the vicinity of Washington, for example, brood rearing is much more actively carried on before this midsummer dearth than afterwards. The main honey flow from tulip tree comes early, and the only later nectar flow of any consequence comes in September, and it often happens that even this yields little surplus. In the typical buckwheat region of the United States conditions are reversed in that the main nectar flow comes after a period of decreased brood-rearing activity in the middle of the major period.

Certain regions, which otherwise, because of lack of nectar from natural sources, would show a tendency toward a midseason slackening of brood rearing, have had this tendency overcome through other agencies, such as the production of honeydew in midseason or by the introduction of plants which secrete nectar under conditions or at times when the native plants do not. This has happened in the southeastern part of the United States through the introduction of cotton and sweet clover. Such circumstances tend to cause brood rearing to remain at a higher level during certain portions of the major period than normally would be the case.

Although the maximum nectar-gathering activity of the season takes place in the major period, the amount of surplus stored is really determined to a large measure during the major period of the preceding season. This is true because the amount of surplus obtained during any season depends on the number of field bees available during nectar flows, and the number of field bees, in turn, depends largely on brood-rearing activity during the initial seasonal expansion. Granting a prolific queen, an abundance of worker cells, sufficient stores, and proper insulation at the beginning of the initial expansion, however, the amount of brood reared during that period will depend largely on the number of bees reared during the latter part of the preceding major period and which have wintered over. It follows, then, that one of the most important aspects of the major period lies in the fact that during it the conditions arise which will lead to success or failure in the honey crop of the next year, so far as the activity of the colony itself is concerned. Most of these conditions are under the control of the beekeeper, and consequently may be provided by him at the proper time. In this same period the beekeeper must also guard against swarming. During the major period, moreover, surplus honey may be consumed needlessly by the colonies instead of being stored, if the colonies did not reach their maximum field strength for the season until after the honey flow was over.

During the initial expansion there is a tendency for all colonies to increase brood-rearing activity regardless of conditions; during the final phase there is an irresistible tendency for all colonies to contract

brood rearing, but only during the major period do colonies exhibit such diverse characteristics in brood rearing as to indicate a response during this phase to conditions which serve to counteract a normal seasonal tendency. It therefore follows that during the major period the beekeeper by his manipulations can best modify the behavior of a colony in the direction which he most desires.

PERIOD OF FINAL CONTRACTION

The period of final contraction represents a continuous decrease in brood rearing during the end of the active season, until by the beginning of the inactive season brood rearing has ceased entirely. A contraction of brood rearing is a normal occurrence before the winter suspension, and is purely a seasonal phenomenon. The decrease may be abrupt, dropping from a high rate of activity to zero in a remarkably short time, as happens in regions characterized by short, active seasons with overlapping honey flows. In regions where there is scarcely any incoming nectar during the latter part of the active season, the final contraction may not be pronounced in its last stages. In short, the rapidity of this decrease is dependent upon the proximity of the last honey flow to the period marked normally by a complete suspension of brood-rearing activities. The greater the quantity of sealed brood in the hive when the seasonal contraction begins and the nearer in time this beginning is to normal seasonal suspension, the greater are the chances for successfully passing through the inactive season, because such a condition in any colony means that it will enter the winter period with far more young bees than will one in which the final seasonal contraction is gradual and covers a relatively long time.

SEASONAL SUSPENSION

In the period of seasonal suspension a complete cessation of all brood-rearing activities takes place in a normal colony which is wintering well. Any brood rearing which occurs during this period is out of season, being abnormal and the result of some harmful factor, such as poor stores, an insufficient number of bees, insufficient insulation, or some outside disturbance of the colony itself. The length of the period of seasonal suspension varies greatly, according to the length of the winter. To bring his colonies through this period successfully is one of the most important problems of the beekeeper, in warm as well as in cold climates. As a matter of fact the problem is often more acute in regions with short inactive seasons than it is elsewhere, not only because there are more flight days but also because there is a less abrupt break from a high level of brood-rearing activity at the end of the previous season, so that colonies under such conditions will have fewer bees at the beginning of the inactive season. Although the large number of flight days is an advantage in connection with the more frequent possession of a poorer grade of honey stores in such localities, it is a disadvantage in view of the fact that useless flights throughout the inactive season rapidly deplete the population of a colony which entered the period of suspension of brood rearing under less favorable circumstances than normally is the case in regions with short active seasons.

DESCRIPTION OF THE COLONIES USED IN 1921

The brood-rearing investigation in 1921, as originally planned, was to be carried out along lines which would tend to show the effects of insulation, of stores, and of the age of the queen. Accordingly, each of the 16 colonies used in 1921 had been wintered in two 10-frame Langstroth hive bodies, eight colonies having been left all winter without packing and eight having been wintered in quadruple packing cases. The colonies were not in any way manipulated for the purpose of changing their brood-rearing rate, except that the addition of frames or supers had some influence in this respect. The record is, therefore, largely a presentation of what bees do without the interference of the beekeeper. The colonies without packing comprised two groups of four, and it was the original intention that the packed colonies should comprise the colonies in two packing cases. Since, however, one of the packed colonies became queenless during the winter, a colony packed in another group was used in its place. The group containing three colonies was unpacked on March 8, while the substituted colony (No. 10) was unpacked on March 21; but the group containing four colonies was not unpacked until May 5. Three of the colonies without packing had queens bred in 1919, whereas all the others, including both those with and without packing, had 1920 queens. Lack of stores was not during 1921 a factor in the brood-rearing activity of the eight unprotected colonies, as each colony proved to have more than sufficient stores for all purposes. Of the colonies packed all winter, four had heavy stores of honey, whereas the other four had light stores, all in the second hive body. The early spring was so favorable for incoming nectar and pollen, however, that each colony except No. 15 had sufficient stores for spring brood-rearing purposes. All the 16 colonies used were located at the Bee Culture Laboratory, Bureau of Entomology, at Somerset, Md., near Washington, D. C.

In an endeavor to determine some of the factors which influence brood-rearing activity during the three phases of the active season, it is of interest to study the seasonal brood records of these 16 individual colonies. For this purpose the general features of the brood-rearing activity in 1921 of 15 colonies are presented here, as well as a somewhat more detailed study of the brood record of an additional colony for two successive seasons. For each of these colonies a seasonal curve (figs. 1 to 16) has been constructed, based on counts (Tables 1 to 16) of sealed brood made from photographic records taken in 1921, as well as an additional curve (fig. 17) for one of these colonies, based on data (Table 17) from 1922. Although at first glance the 17 curves seem to show little correlation, they reveal definite relationships on closer study. The apparent differences result from abnormal conditions within individual colonies, which caused modifications in the brood-rearing responses. On the whole, the 17 curves point to certain more or less definite and constant seasonal variations in brood-rearing activity, due to normal, seasonal stimuli, but subject to modifications by the presence of any abnormal factors. This fact becomes apparent upon an examination of the two successive seasonal curves presented for colony No. 4.

It may be noted in passing that, even before unpacking colonies wintered in two hive bodies in quadruple packing cases, removal of frames from the lower hive bodies can be accomplished readily by

the following method: Before packing, three frames in the lower hive body are replaced by two chaff division boards the lugs of which have been sawed off. After removing the frames in the second hive body these division boards in the lower hive body can be pulled out easily, and the space created by their removal is then sufficient to allow removal of the frames which were there with them. The space occupied by two packed division boards of the type commonly manufactured is equivalent to that occupied by three Langstroth frames.

SEASONAL CHARACTERISTICS OF 1921

In the season of 1921 the weather conditions at the location of the bureau apiary were not favorable for a maximum honey crop. Although warm weather in late February and the fore part of March had brought out fruit bloom and other flowers somewhat prematurely, and although the thermometer registered as high as 90° F. (32.22° C.) on March 27 and 28, on March 29 and 30 most of this early bloom was destroyed by frost. On the morning of April 1, moreover, traces of snow were visible on the covers of the hives. During the fortnight beginning March 29, with one exception, when 59° F. (15° C.) was the minimum registered, the temperature dropped each night well below the clustering point (57° F., 13.89° C.) even reaching the freezing point on six occasions. One 96-hour period had a maximum of only 62° F. (16.67° C.) and a minimum of 29° F. (-1.67° C.). On four occasions 57° F. (13.89° C.) was the highest temperature recorded during a 24-hour period. Slight precipitation occurred on eight days of this fortnight. Such weather curtailed pollen and nectar gathering, which had just before been going on very actively.

Warmer weather set in again with the middle of April, and continued until the end of the summer, although there were a few days of cold, rainy weather in early May. The temperature during April ranged from 29° F. (-1.67° C.) to 96° F. (35.56° C.); in May, from 39° F. (3.89° C.) to 93° F. (33.89° C.). Rain on six consecutive days, beginning with May 11, spoiled the chances for a large yield from black locust (*Robinia pseudacacia*). On May 18 the tuliptree (*Liriodendron tulipifera*) began to yield nectar, but a four days' rain beginning May 23 put an end to nectar from this source. Nectar was available in small quantities from other sources during the latter half of April and throughout May.

During practically the whole of June much honeydew, as well as pollen, was available, and for a short time after June 15 a slight amount of nectar from basswood (*Tilia* spp.) and sweet clover (*Melilotus alba*) was collected. During July little nectar came in, although during the week beginning July 15 a small quantity of pollen was brought into the hive. Beginning August 3, and throughout the rest of the month, pollen was carried into the hives in large quantities, and it was fairly abundant during September. Beginning September 12 and continuing until the end of that month a small nectar flow from various Compositae was on. October proved to be a period of little activity as far as pollen or nectar gathering was concerned.

BROOD REARING OF A TYPICAL COLONY FOR TWO SUCCESSIVE SEASONS

Of the 16 colonies used in 1921 the seasonal brood-rearing record of one (No. 4) during 1921 and 1922 has been chosen as normal and as typical of the whole group. This colony stored the most surplus honey during the two successive seasons and its seasonal brood-rearing curves for the two years are strikingly similar, taking into consideration certain minor differences due primarily to weather conditions. During the winter preceding each of the two seasons this colony was left without packing in two 10-frame Langstroth hive bodies with abundant stores of honey. Nothing additional was done to stimulate brood rearing in the course of the two years except to furnish an abundance of room at all times, the queen having free access to all hive bodies. In 1921 the first super, or third hive body, was given to the colony on April 26, whereas in 1922 the first super was given on April 14. In both seasons the queen still had plenty of room in the original two hive bodies at the time the third hive body was given. Other supers were given later, so that in 1921 the colony had a maximum number of five hive bodies, and in 1922 a maximum of six. Owing to the policy adopted of providing an abundance of room at all times, not only for incoming nectar but for the egg-laying activity of the queen as well, the total number of hive bodies furnished during each season provided one hive body in excess of the actual minimum requirements of the colony. No added hive bodies were removed until October in either year; in 1921 the number was reduced to two on October 11, and in 1922 the same was done on October 16. Although there was no restriction to any possible expansion of the brood area, on no occasion was brood found above the lower three hive bodies. The same queen was used throughout both seasons, having been introduced into the colony in late summer in 1920 as soon as she had commenced to lay. For purposes of identification her left wing was clipped in July, 1921. In brief, each spring found this colony with a fairly strong force of bees, a prolific queen, combs composed chiefly of worker cells, and no shortage of honey stores.

INITIAL EXPANSION, COLONY NO. 4

In each of the two years of this experiment, as shown by observations, the chief source of nectar, tuliptree, was yielding freely by May 21. For these years, then, the maximum amount of sealed brood should have been attained during the last week in April, but in neither 1921 nor 1922 did the maximum brood-rearing correspond with ideal conditions. (Figs. 4 and 17 and Tables 4 and 17.)

In 1922 the maximum amount of sealed brood was reached during the first week in May, whereas in 1921 this maximum was not attained until about two weeks later, although a more auspicious beginning had been made occasioned by the unusually early spring. Nectar and pollen came in abundantly throughout March, but the secretion of nectar and the production of pollen were affected adversely by the inclement weather at the end of March and beginning of April, and probably the lower temperatures also affected unfavorably the activity of the unpacked colony. The adverse conditions finally checked the initial seasonal expansion of the brood, as is shown by a decrease in the amount of sealed brood in the latter half of April,

1921. A recovery in the rate of brood rearing was made subsequently, but at a time when factors associated normally with the major period were making themselves felt. It follows that the maximum amount of brood rearing in 1921 was not purely the result of the initial seasonal tendency.

In 1922, on the other hand, there was a late spring, inclement weather in early March causing a temporary shortage of pollen in the hive. These conditions restricted somewhat the initial seasonal tendency, as is clearly evidenced in the brood curve for that month. In spite of this beginning, April weather proved so favorable that by the end of the month the principal sources of nectar were as far advanced as in the previous year, and brood-rearing activity became so pronounced that the maximum for the season was practically reached before factors peculiar to the major period became dominant. In fact, the maximum in sealed brood in 1922 was attained in advance of the tuliptree honey flow, and about two weeks in advance of that of the previous year.

THE MAJOR PERIOD, COLONY NO. 4

In 1922, the more typical year, the beginning of the major phase was marked by a maintenance of brood rearing at the highest rate of the year (fig. 17). Since the maximum had been attained just before the locust bloom, the high rate was kept up for a couple of weeks. During the week of maximum sealed brood, brood rearing was undoubtedly still being carried on under the impulse of the initial tendency, but influencing factors characteristic of the major period were also becoming evident. The week of the maximum marked the point of division between the initial seasonal tendency and the major period. Nectar subsequently coming in from the tuliptree tended to restrict the queen, and after this honey flow there was a dearth of nectar until the middle of September. During June, however, there was an appreciable amount of incoming pollen, and in August there was an intense pollen yield. As a consequence the decline in brood-rearing activity which set in with the beginning of the tuliptree honey flow and extended until the intense pollen yield in August was broken by a slight increase in June, in response to the pollen yield. The increase in August, on the other hand, was very pronounced. This was followed by a decrease until incoming nectar, chiefly from goldenrod, made itself felt by another slight increase in the brood area.

In the main, brood-rearing activity during the major period of 1921 was very similar to that for 1922. In the month of June, 1921, the increase in brood rearing was more pronounced, for two reasons. In the first place, instead of a gradual decline following the peak, as in 1922, a sharp decrease occurred in 1921. This happened because just prior to the honey flow the queen had ascended to the third hive body to lay, there being already at that time an extensive brood area in this hive body. Incoming nectar, however, so quickly cut down the number of cells available for the queen as to force her soon to return to the second hive body. Here, too, so many available cells within the brood area proper had been filled with nectar during her absence that the total number of cells made empty either by emerging bees or by consumption of stores did not suffice during that week to permit keeping up her former rate. During the next two

weeks, with the emergence of many bees in both the second and third hive bodies, the queen had more room and was able to approach a rate comparable to that attained in the same period of the following year. In the second place, there was an exceptionally large quantity of honeydew available, associated with incoming pollen during June, and also a certain amount of nectar from sweet clover. Throughout this month the queen had all the room needed for a normal response to these stimuli. In both seasons, after July 1, the brood curves follow parallel courses during the remainder of the major periods. At the end of July in each season brood-rearing activity had been reduced to approximately one-half that represented by the maximum of the same year.

FINAL CONTRACTION, COLONY NO. 4

In each year the final seasonal contraction in brood-rearing activity took place almost entirely in October, covering only three weeks in 1921 and four weeks in 1922. The abruptness of the contraction in these few weeks is shown from the fact that in the last week of September there were practically half as many cells of sealed brood as were found in the maximum counts for the respective years. As a result, the colony entered each following season strong in bees.

The brood-rearing record of this colony, although not ideal, is the most satisfactory of any of the 16 colonies because the maximum brood rearing bears some correlation to the initial expansion. The portion of the major period immediately following the period of main nectar secretion is not marked by a disproportionate degree of brood-rearing activity. In the late stages of the major period, moreover, there is an increase in brood rearing, providing a sufficient number of newly emerged bees at the beginning of the final contraction to insure successful wintering and an auspicious beginning of the next active season. That conditions within the colony remained nearly constant during the two consecutive years is indicated by the striking similarity in the curves of brood-rearing activity during both active seasons. (Fig. 18.) At the beginning of the experiment this colony was fairly strong; and, although it was subjected to no special manipulations except to have plenty of room and stores available at all times, it was fully as strong in bees at the beginning of the seasonal suspension in the fall of 1922 as it was in early spring in 1921. The performance of this colony, therefore, leads to the conclusion that, other conditions being equal, a strong colony tends to remain strong.

GENERAL OBSERVATIONS ON THE REMAINING COLONIES

Having given the record for colony No. 4 in some detail for the two seasons, it is not necessary to discuss so minutely the records of the remaining colonies observed during the season of 1921. Only the outstanding points regarding the various colonies will be considered. Unless otherwise stated, all colonies lived through the winter of 1921-22.

Colony No. 1 had been wintered without packing but was provided with an abundance of stores and had a 1920 queen. The brood-rearing activity of this colony furnishes a good example of the response of a mediocre queen to such a combination of factors as sufficient stores, sufficient worker bees, and sufficient brood cells at the

beginning of the active season. During the initial expansion a rate of brood rearing was reached almost equivalent to that at the height of the whole season. In fact, the amount of sealed brood (fig. 1 and Table 1) indicates no striking fluctuations in the rate of brood rearing during the three months when this was most active. Even the continued addition of many young bees to the population of the colony during this time failed to heighten the brood-rearing activity. The cold weather of April, the nectar flow of May, the honeydew and pollen yield of June, the pollen of August, and the nectar flow of September, may all be traced by the variations in the quantity of sealed brood. The response to the stimulus in August was only slight. In relation to the number of bees reared during the major period, the initial expansion was not nearly enough pronounced, nor did the final contraction represent a large enough break in brood-rearing activity to insure successful wintering. This colony died during the winter of 1921-22, leaving only a small quantity of stores in the hive.

Colony No. 2 also had a 1920 queen, plenty of stores, and had been wintered without packing. Although this queen was more prolific than the queen in colony No. 1, as is shown clearly by the curves of sealed brood for these colonies (figs. 1 and 2, Tables 1 and 2), there were not sufficient bees in the colony at the beginning of the active season to cause the maximum brood rearing to be correlated closely with the initial expansion. The maximum was reached only in June, after the population of the colony had increased sufficiently over that obtaining during the initial expansion to take care of an enlarged brood area. This rate was reached coincidentally with the honeydew yield in June. As the incoming honeydew was placed within the brood area, restricting the number of cells available to the queen, an abrupt decrease in brood rearing followed in the week immediately after the maximum. A partial recovery in the rate of brood rearing occurred along with a relatively small pollen yield in July, after which, with one exception, brood-rearing activity decreased continuously until the September nectar flow. This exception took place during the pollen yield of August, as is shown by the fact that at this time the curve remained at about the same level for one week. The brood-rearing activity of this colony shows the same responses to weather and incoming pollen and nectar as have been noted for colonies 1 and 4, there being, of course, differences in degree. The maximum brood-rearing activity of the season came after the major period was well advanced, and is consequently too much out of proportion to the initial expansion to represent ideal conditions.

Colony No. 3 was wintered without packing, had been given heavy stores, and had a 1919 queen. This queen had enough bees at the beginning of the active season to support her maximum egg-laying activity, as is shown by the fact that scarcely any more sealed brood was found in the hive on any occasion in May than had been found during the initial expansion in March and April. (Fig. 3 and Table 3.) Because the queen was old and about worn out, incoming nectar in May soon severely restricted her activity, the result being a marked drop in the brood rearing for that month. At the beginning of May she had been crowded out of the second hive body, in which she had been laying almost exclusively, into the lower hive body. Even there

the brood area was quickly hedged about by incoming nectar, with the consequent great reduction in cells available for egg laying. Emerging bees made more room available in June; and consequently, under the stimuli of incoming pollen and honeydew, the queen's activities were increased to a limited extent. After this there was a continuous decrease in brood rearing until the old queen was superseded in August. The colony had been endeavoring to supersede her since May, but all queen cells had been removed as soon as found. Finally one was left intentionally, from which a virgin emerged. The colony had become rather weak by August, however, and the curve shows no apparent response to the pollen yield of that month, although the old queen was still alive. The new queen had mated and had commenced to lay by August 25. During the nectar flow of September she attained a rate which compared favorably with that attained by the old queen even during the initial expansion. Owing to the fact that the old queen was failing, the brood-rearing responses of this colony to nectar and pollen yields are not so clearly shown as in colonies with more vigorous queens. The effect of the April weather is, however, very apparent.

Colony No. 5 (fig. 5 and Table 5) was wintered without packing, had a 1920 queen, and was provided with abundant stores of honey. In fact, the second hive body was so well filled with honey that the queen was cramped for room in late March, and it was deemed advisable to replace two frames of honey in the second hive body with empty frames. Although before these empty frames were substituted the queen had reached the limit of room for egg laying in the second hive body, scarcely any brood was reared in the lower hive body until May or June, even though plenty of room was available there in March. Before the cold spell in April there were more than sufficient bees in the hive to take care of brood in all available cells in the second hive body, but not enough to maintain in addition a large brood area in the lower hive body. The addition of the two extra frames permitted an expansion of the brood area in the second hive body, and the amount of sealed brood mounted slowly, even during the cold weather. During this period, however, the queen laid no eggs in the lower hive body.

In her activities the queen kept pace with the ever-increasing number of young bees from the first part of April until the maximum of the season. During this period, nevertheless, brood-rearing activity suffered a slight check in May, at a time when much pollen and some nectar were coming in. No super had as yet been given the colony, and, as much of the pollen and nectar were being deposited within the brood nest proper, the queen was once more cramped for room. A super given at this time relieved the shortage of room and furnished storage space for what little surplus was gathered during the tuliptree nectar flow immediately following, and more particularly during the honeydew yield of June, when the maximum brood-rearing activity of the season was attained. During the dearth of nectar immediately afterwards, brood-rearing activity fell off noticeably until stimulated by the pollen yield in August. From the height of the response to this stimulation until the beginning of the September nectar flow, brood-rearing activity underwent another striking decrease. There was somewhat of an increase in September, which, although rather conspicuous on the curve, was not nearly great

enough to insure the best wintering conditions. The greatly diminished brood-rearing activity during the latter part of the major period must be attributed to a failing queen, because at any time after July, except for that drawback, there were sufficient bees, stores, and room to have resulted in a much greater amount of brood during August and September.

Seasonal brood-rearing activity of the type represented by this colony is anything but satisfactory from the standpoint of obtaining a honey surplus. Owing to lack of room, the initial expansion did not have a chance to proceed normally, even though sufficient bees to meet the queen's egg-laying capacity were not on hand. As a result of having its early development arrested and retarded, the initial expansion became merged with the major period. Owing to lack of sufficient bees, brood-rearing activity increased with relative slowness, even after sufficient room had been provided. As a consequence, the maximum of sealed brood was not attained until too late for the resulting bees to be useful in gathering nectar for surplus. Comparatively slight brood-rearing activity at and preceding the final contraction spelled danger to the colony in the coming winter, and well illustrates the evil results of failure to requeen at the proper time. This colony died in the winter of 1921-22, with some honey still remaining in the hive.

Colony No. 6 (fig. 6 and Table 6) had a 1920 queen, stores in abundance, and had been wintered without packing. For this colony, there is no sharp distinction between initial expansion and major period. Colony No. 6 had an overabundance of stores in the second hive body in early spring, thus restricting the queen; but it did not have enough bees to permit expansion of the brood area downward into the lower hive body at the rate at which it was begun in the second hive body. There occurred, therefore, a slight diminution of the brood area at the end of March, but the colony so increased in population during the fore part of April as to provide more than enough bees to take care of brood in all the cells available. Brood-rearing activity consequently increased to the maximum in late May, excepting another slight break in April, caused by weather conditions. Following the maximum there was a rather abrupt decrease due to the presence of fresh nectar temporarily within the brood nest. A super added during the last week of May partially provided room for the honeydew in June, and thus tended to eliminate further restriction of the brood area. In fact, an increase in brood rearing took place in June. Although the queen had reached in May her maximum for the year, she was able to make a noticeable increase in her rate, even in July, after having dropped off from her maximum for June. It may be added that some pollen was coming in at this time. A decrease then followed which lasted until September. Possibly owing to the July increase, the response to the pollen yield of August is apparent only as a slight diminution in the rate of decrease. However, a pronounced increase in brood rearing took place during the September nectar flow. The initial expansion of the colony is merged too completely with the major period. During the major period there was too much brood rearing, resulting in a useless consumption of stores.

Colony No. 7 (fig. 7 and Table 7) had a 1919 queen and sufficient stores and had been wintered without packing. Sufficient bees were

in the colony at the beginning of the initial expansion to have supported a greater rate of brood rearing than was attained. Sufficient cells were also available, but the queen was evidently too old to have made any better showing than she actually did. Her maximum was reached during the initial expansion. A rate nearly equal to the maximum was maintained for about a month, and then a decline set in which reduced brood-rearing activity to practically zero by the end of August. At that time the old queen was superseded. The brood-rearing activity of the new queen, even in September, equaled that of the old queen during the initial expansion. The fact that this colony at the beginning of the active season did not have a queen prolific enough to allow it to carry on brood rearing at a rate consistent with its strength in bees, available brood cells, and honey stores, accounts for the fact that it does not exhibit all of the responses to seasonal phenomena found in the other colonies.

Colony No. 8 (fig. 8 and Table 8) also had a 1919 queen, had been without packing all winter, and had plenty of stores. This colony had the poorest queen of any of the 16 colonies used. During the initial expansion she attained almost her maximum rate for the season. The cold weather in April caused a slight decrease, but her maximum was reached in early May. Incoming nectar in that month restricted her activity and a decline followed. On August 18 the colony was queenless. A virgin queen emerged during the next week but never mated. Finally on September 8 a young queen was introduced which began to lay on September 15, but was lost two weeks later, after having made a good start. Another queen was introduced successfully in October, but too late to produce much brood.

Colony No. 9 was unpacked on March 8, had sufficient stores and a 1920 queen. The curve of sealed brood for this colony (fig. 9 and Table 9) is typical of a queen which lays at her maximum rate during the season, the rate being fairly uniform during most of the major period. As this was a packed colony, only seven frames were in the lower hive body. The three frames completing the normal number were not added until the last week in March, and the colony became somewhat crowded for room, thus restricting the queen during the period of initial expansion. The added combs helped to relieve the brood area proper from further restriction by pollen, with possibly a little nectar. The fact that the queen was utilizing only the second hive body at the time of the inclement weather in April, coupled with the fact that there were more than sufficient bees on hand to allow an expansion of the brood area even at this time, resulted in an increase of brood rearing during April until the maximum of the season was reached at the end of the month. From that time until late August, when this queen was naturally superseded, brood was reared at a fairly uniform but generally decreasing rate. Although an excess of room was provided, so that this queen was restricted in no respect, there were but slight reactions to the nectar of May and the pollen and honeydew of June. Supersedure interfered with the response to the pollen yield of August, although there are indications that the response had already begun before the new queen emerged. She was laying by the beginning of September. The increase in brood rearing during that month was due probably not only to the incoming nectar but to the presence of a young queen as well. Criticism of the

seasonal brood-rearing activity of this colony may be put in two ways. It may be said either that brood rearing during the initial expansion did not sufficiently exceed that maintained during the larger part of the major period, or that brood-rearing activity during the larger part of the major period was continued too nearly at the same rate as during the initial expansion, thus causing too large a consumption of stores in the hive in rearing brood uselessly and in feeding an idle population.

Colony No. 10 (fig. 10 and Table 10) began the season under ideal conditions as far as the queen herself was concerned, and was unpacked March 21. The original queen had been introduced in 1920, had plenty of bees, room, and stores, and consequently attained her maximum rate of brood rearing during the period of initial expansion. The weather apparently had little effect on the activity of this queen; the decline from the maximum of the season is rather gradual and the subsequent increase is made slowly. The colony had plenty of room, but the nectar in May received a relatively slight response. The queen was not seriously restricted by incoming nectar, and probably was laying at her maximum capacity. A further slight response was brought about by honeydew in June. In July, however, the queen was lost and brood rearing dropped off abruptly. A virgin queen was reared which mated and began laying in August. This queen soon reached the limit of empty brood cells, as the brood nest had become rather well filled with pollen and some nectar. Two empty frames were therefore placed in the second hive body, which were promptly used by the queen. As a result of this additional room the queen had all the cells necessary during the remainder of the season. The initial expansion of the season was timely enough, but it was not sufficiently greater in activity than was brood rearing during June and July to spell success in surplus. The final contraction presents fairly satisfactory conditions.

Colony No. 11 (fig. 11 and Table 11) afforded the best illustration of any of the 16 colonies of what may be accomplished during the initial seasonal expansion if conditions within the hive are favorable. This colony had a 1920 queen, was unpacked on March 8, and had no more stores than were sufficient to meet brood-rearing requirements before early nectar began coming in; a condition which gave the queen a maximum amount of room. Besides these factors, there were at the beginning of the active season plenty of bees and a prolific queen. Under the spur of the tendency toward the initial expansion, the brood area increased with great rapidity. At the time of the change in weather conditions in April, the brood area had been expanded so far that a further expansion was not possible and a break occurred. A recovery was soon made which culminated in May, when incoming nectar caused another restriction of the brood area. During June a short-lived recovery was made which was terminated by a decrease, probably due in part to a restriction of the brood area by honeydew, but more likely to the absence of any great stimulus toward increased brood-rearing activities during July. Even so, the queen continued active enough to respond in a small degree to the minor pollen yield in July. Owing to the large number of field bees on hand in August, the brood area was so restricted by the quantities of pollen brought in that the queen was unable to make much of a response. In fact, a rapid decrease followed

this pollen yield, and continued until the fall nectar flow. Increased brood-rearing activity under this new stimulus was slight in comparison with that under stimuli earlier in the season. Notwithstanding the fine example of an optimum initial expansion represented by this colony, brood rearing was a little too active in proportion in May, and especially so in June, and exhausted uselessly what little nectar had been gathered in May.

Colony No. 12 had a queen which attained her maximum capacity during the initial expansion. This colony was unpacked March 8, had a 1920 queen and stores just sufficient, leaving plenty of room available for brood rearing. The April decline, characteristic of so many of the other colonies, appears to have been for the most part avoided in this colony, probably because of the presence of a large number of bees. Although April weather may have prematurely ended the initial expansion, the fact that, excepting one sporadic occasion, the quantity of sealed brood did not at any time equal the quantity found at the height of the initial expansion, tends to show that the queen was laying throughout at about her maximum capacity. The curve of sealed brood (fig. 12 and Table 12) shows a decrease in early May, followed by an increase later in the month which may be correlated with the tuliptree nectar flow. The increase, however, did not bring brood rearing up to the maximum attained during the period of initial expansion. A decrease followed the May increase; but it was checked in part by the incoming honeydew and pollen, after which there was a sporadic upshoot at the very end of this period. From that time on there was a marked, rapid decrease in brood rearing until the queen was superseded in August. The new queen was laying on August 16 and quickly attained a relatively high rank in September, but unfortunately was lost in that month. A new queen emerged and mated but did not begin to lay until October 4, too late to make much of a showing. The two peaks in the curve, following the maximum of the initial expansion, disturb the proportions of an ideal curve; but the bees reared during these two increases in the brood-rearing rate doubtless enabled the first new queen to establish the good record to her credit.

Colony No. 13 (fig. 13 and Table 13) was unpacked on May 5 and had a 1920 queen and more than sufficient stores. At the time of the bad weather in April practically all available cells were in use either for stores or for brood, the lack of available brood cells accounting largely for the April decline shown. A super was added on April 29 which, with three frames placed in the lower hive body instead of the packed division boards, provided plenty of room. Brood rearing then so increased that the maximum of sealed brood was reached the second week in June. In May incoming nectar interfered slightly with brood rearing just prior to the maximum, and honeydew caused a further restriction just after the maximum. The rate then became stable for a few weeks until the queen disappeared. A virgin was reared naturally which mated and began to lay on August 19. Brood-rearing activity was carried on at a fairly rapid rate, but suffered a slight check just prior to the September nectar flow, incoming pollen causing a restriction in room. The peak attained in September was sufficiently high to insure plenty of bees for winter. As the maximum brood-rearing activity came in the major period after the main honey flow was over, there was no occasion to expect a large honey crop in 1921.

Colony No. 14 (fig. 14 and Table 14) had neither sufficient bees nor sufficient room to allow the queen to lay eggs at her maximum rate during the initial expansion. This colony had a 1920 queen and an abundance of stores. The large quantity of stores, both in the upper and the lower hive bodies, reduced the area available for brood rearing to less than the requirement of the colony. This condition was rendered more acute by the fact that until the time of unpacking, May 5, there were only seven frames in the lower hive body. The effect of lack of room is visible in the brood curve at the end of March. At this time, to give more room, a frame in the second hive body was replaced by an empty brood frame, with the result that there was a slight increase in brood rearing. This extra space was not sufficient, however, for the incoming pollen and nectar and for the brood. A decline in April resulted from this factor and from any influence of the weather. A super was added in the last week in April, shortly before the colony was unpacked. This relieved the congestion, and in May the brood rearing rose well above the height attained during the initial expansion. That the maximum was not attained until June is evidence of the fact that there were not sufficient bees in the hive from the latter part of April, when an abundance of room became available. After June came the normal seasonal decrease in brood rearing, lasting until pollen in August produced a rather long-continued response. Following this another decrease occurred until goldenrod nectar made itself felt. Owing to a large number of field bees the brood nest became much hemmed in. The brood-rearing record of this colony was entirely unsatisfactory from the standpoint of the honey producer, because the height of brood rearing came after all chance of storing surplus was past, and was so pronounced that to maintain the colony's new population meant serious inroads on what nectar had been gathered.

Colony No. 15 (fig. 15 and Table 15) was unpacked on May 5, had a 1920 queen, light stores, and not sufficient bees to allow brood-rearing activity to keep pace with the egg-laying activity of the queen. This was the only one of the four packed colonies (Nos. 11, 12, 15 and 16) provided with light stores which showed any diminution in brood rearing directly traceable to lack of honey stores. When observations on this colony were first made in March, 1921, the honey stores were found to be low. Not being so strong in bees as the other colonies just mentioned, it was not able to gather so much nectar during March, and therefore had to use proportionately more reserve stores in that month. The records of sealed brood reveal a check to the brood-rearing rate in late March, followed by an increase. The fact that this increase took place within two weeks after giving the colony a full comb of honey in the lower hive body is an evident indication that, at the time the extra comb of honey was given, there was neither sufficient honey in the hive nor sufficient nectar coming in to support any great increase in brood-rearing activity. The increase was only short lived, because at the time of the cold spell in April the brood area had become as large as could be covered by the bees in the hive during such weather. The queen was necessarily restricted to this area for the time being, and as a large part of the brood in it remained sealed for several days she did not have sufficient cells available for further egg laying. The emergence of young bees, however, gave her a chance to refill the cells in this

area, as is shown by a rise in the curve during the first week of May. In the meantime, however, the upper edges of this area had been cut off by incoming nectar and pollen. Field bees had been kept busy during the latter part of April after the cold weather, although nectar was not very abundant. To relieve the resulting congestion, a super had been given in the last week of April, about a week before unpacking, and on unpacking three more frames had been placed in the lower hive body to take the place of the packed division boards. With this extra room the queen was able to expand the brood area in proportion to the number of nurse bees. The result was a sharp rise in May to a maximum which was maintained throughout most of June. During this period there was plenty of room in the hive to provide cells for the activities both of the field bees and of the queen. From the latter part of June until the pollen yield of August the activities of the queen became more and more restricted, excepting a brief response to pollen in July. A fair response was made to the pollen yield of August. By this time the large number of bees which had emerged during June, plus the brood reared after that month, had depleted the honey stores to a point which caused a serious diminution of brood-rearing activity between the pollen yield of August and the nectar flow of September. In the spring the colony had not suffered from want of stores but had no great surplus; during the May nectar flow and the greater portion of the honeydew yield in June sufficient field bees had not as yet developed to add much to the surplus stores. Consequently during the summer practically all of the honey stores were consumed. To save the colony it became necessary to add three full combs of honey to the second hive body in the second week in September. This factor, coupled with the oncoming nectar flow, caused another increase in brood rearing. By the second week in October honey stores were practically depleted once more, and it was necessary to add more frames of honey. Under such circumstances brood rearing had not progressed actively enough just prior to the seasonal contraction to afford this colony an optimum number of bees for winter. The whole curve is highly unsatisfactory, because the initial expansion does not represent sufficient brood-rearing activity and because too wide a gap separates the maximum activity of the major period from the initial expansion. At the end of the season there is also too wide a gap in the continuity of the curve for the major period between the point of demarcation of the seasonal contraction and the next preceding high point of the major period.

Colony No. 16 had a 1920 queen, light stores, and was unpacked on May 5. Although the brood curve for this colony (fig. 16 and Table 16) shows a rather rapid and early initial expansion, there were not quite enough bees for the queen. During the initial expansion the queen was utilizing all of the 10 frames in the second hive body. She had reached the limit of the area of brood which could be cared for in March, however, and a slight decrease followed. With the emergence of young bees more room was available within the brood area, and the queen began to take advantage of this, but was restrained somewhat by the cold weather in April. When the warm weather came, before the queen could take possession of all the cells made available by emerging bees, a large number of cells had already been used for incoming nectar and pollen, resulting in a striking drop

in the curve. As a matter of fact, at one time the queen was confined to one side of the brood area by a comb filled almost entirely with fresh nectar. More room was given by the addition of a super during the last week in April. Unpacking on May 5 meant the addition of three frames in the lower hive body to replace the packed division boards. As a result, both of the extra room and of the stimulation of the May nectar flow, brood-rearing activity expanded back to the level attained in March. Incoming nectar occasioned a slight decrease during the latter part of May, but feeding of larvæ on hand soon removed this restriction. The maximum of the season was attained in June, but soon gave way to a sharp decrease brought about by incoming honeydew. A partial recovery was made, which in turn was stopped by another decrease because the brood area had been so restricted by honeydew that few empty cells were to be found. More room was available within the brood area proper at the time of the small pollen yield in July, which resulted in an increase followed by a decrease. Loss of the queen at this time then caused a suspension of brood rearing. A virgin was reared, which mated and began laying before the September honey flow. As in the case of colony No. 15, there is too wide a gap between the initial expansion and the main activity of the major period, and also too much of a break in the continuity of brood rearing just prior to the final contraction for this colony to have had the proper population during the various phases of the active season.

GENERAL DISCUSSION OF THE RECORDS FOR 1921

The brood-rearing records of these colonies show the region about Washington to be one in which seasonal brood-rearing activity tends toward slackening during the major period. The main brood rearing of the season comes before the occurrence of this tendency; but, following it, brood-rearing activity increases in normal colonies sufficiently to provide an adequate number of bees for winter.

INFLUENCE OF POLLEN AND NECTAR

Throughout the season direct responses were made to incoming pollen and nectar. The main nectar flows of the year come during the forepart of the active season, which is also normally the time of greatest brood-rearing activity. During July scarcely any fresh nectar is found, and brood-rearing activity is greatly diminished. In September there is a nectar flow, and associated with it is heightened brood-rearing activity. The correlation between a good pollen yield and brood rearing is well illustrated by the expansion of the brood areas during the pollen yield of August. That there will even be a response at times to a light pollen yield is shown by the colonies (Nos. 2, 6, 11, 15, and 16) whose brood-rearing activity did not decrease continuously throughout July. For the most part, owing to abnormal circumstances, conditions within these colonies did not become conducive to maximum brood-rearing activity until just before the period of nectar dearth; as a result, only a slight stimulus was needed to create a response in such colonies. That definite brood-rearing responses will be made from year to year to certain constant seasonal stimuli, other conditions remaining equal, is well brought out by the brood records of colony No. 4 for 1921 and 1922.

CONDITIONS WITHIN THE HIVE

The value of insulation in early spring is not demonstrated clearly in the case of these colonies because virtually summer weather prevailed in March, thus producing conditions within the colonies which tended to offset in a measure any evil effects of the cold weather in early April. Unfortunately, too, the colonies (Nos. 13, 14, 15, and 16) which were left packed until May suffered from lack of room just at the time of the unfavorable weather, so that no comparison may be made with them. Of the colonies left all winter without packing four (Nos. 5, 6, 7, and 8) present such abnormal conditions due both to lack of room and to failing queens as to offer little light on this subject. The other four colonies, which were not packed for winter, however, did not suffer from lack of room, and, although each differed as to prolificness of queen and colony population, each shows a break in brood rearing associated with the cold weather of the fore part of April. Colony No. 4, nevertheless, had sufficient bees to overcome quickly the effect of this weather and to proceed to the maximum brood-rearing activity of the year. Although the brood-rearing activity of three of the colonies (Nos. 9, 10, and 12) unpacked in March appeared to be somewhat restricted during early April, the later performance of the queens in these colonies and the fact that no great decrease in brood-rearing activity immediately took place, indicate that sufficient bees were on hand to keep up the temperature of the brood area in its entire extent at that time, and even to have cared for a larger area had the queen been capable of increased egg laying. The brood area of the other colony (No. 11) which was unpacked in March shows a decided restriction following the cold weather. Although a comparison of the direct effect of adequate insulation on brood rearing can not be made from the brood records of these colonies in 1921, the fact remains that the colonies minus packing which were most normal did suffer a setback in brood rearing as a result of the cold weather. A strong colony without packing, like No. 4, shows, however, a certain amount of resistance to the effects of such weather.

CONDITIONS OF THE COLONY

The influence on brood rearing of the three important factors, prolificness of queen, colony population, and brood cells available, becomes so interwoven in certain colonies that it is hard to trace the separate influence of each. The important part played by colony population in determining when the maximum brood-rearing activity of the season will take place is well illustrated by colony No. 2, which reached the maximum of the brood-rearing season relatively late. In this colony lack of population was beginning to restrict the brood area somewhat, even in late March. Population of colony accomplishes little in itself if the queen is not prolific. The brood records of colonies Nos. 3, 7, and 8 all attest this fact. It so happened that each of these queens had been introduced two seasons previously. On the other hand, the queen of colony No. 4, in 1922, the second season after her introduction, made as good a record as in 1921. This shows that in certain instances, at least, the value of a queen can not be determined merely by her age.

STORES

As already stated, none of the 16 colonies suffered from lack of stores at the beginning of the period of initial expansion. No data were obtained, therefore, showing the effect of want of stores on brood rearing. It was evident, however, as soon as nectar became prematurely available from fruit bloom, that certain colonies had such an abundance of stores as to result in lack of room for any expansion of the brood area. The history of colony No. 14 brings out this fact, although in this instance colony population also influenced the result. The importance of having sufficient stores in early spring until incoming nectar supplies the current needs of the colony, and the need of room sufficient to offer no check to the initial expansion, should emphasize to users of the Langstroth or other hive bodies of equivalent size the value of wintering a colony in two hive bodies, and show that otherwise a full population for the honey flow is liable not to be attained.

OBSERVATIONS IN 1920

It has been thought of interest to introduce at this point the work done by Lloyd R. Watson in 1920, while he was connected with the Bee Culture Laboratory. As already stated, through direct counts of all eggs, larvæ, and sealed brood, he was able to obtain in that year a total of five seasonal brood records. (Tables 18 to 22.) It must be borne in mind that the curves (figs. 19 to 23) based on these records represent a total of all eggs, larvæ, and sealed brood, whereas the curves (figs. 1 to 18) based on photographic records made by the writer represent sealed brood only. Furthermore, the curves for 1920 are not drawn to the same scale as are the other curves in this paper. These differences in themselves would be sufficient to cause the curves to present apparent discrepancies in the time and degree of response even to the same stimuli. Unfortunately, too few data on each colony are available, other than the actual counts of brood, to warrant a close correlation between the brood records for 1920 and those already discussed. Nevertheless, the results for 1920 are in line with those presented for the succeeding years.

Each of the five colonies (A, B, C, D, and E) had been wintered in two hive bodies in quadruple packing cases. Colonies C, D, and E were unpacked on March 17, while colonies A and B were left packed until April 13. In August, 1919, a young queen had been introduced into each colony. All the colonies were well provided with stores.

In 1920, as in 1921, there was a period of cool weather during early April. From April 4 to April 11, inclusive, the minimum and maximum temperature corresponded roughly with the freezing point (32° F., 0° C.) and the clustering point (57° F., 13.89° C.) respectively. In fact, with two exceptions, the minimum temperature on each day of this period was below 32° F. (0° C.) whereas on only two occasions does the temperature record for any day within this period show a maximum of over 57° F. (13.89° C.). The two exceptions to the minimum are April 4, with a minimum record of 39° F. (3.89° C.), and April 5, with a minimum record of 43° F. (6.11° C.). The two exceptions to the maximum occurred on April 9 and April 11, the former having a maximum of 61° F. (16.11° C.), the latter of 64° F. (17.78° C.). The data available as to honey flows show that the most nectar of the year was gathered during the last half of May.

In 1920, contrary to conditions in 1921 and 1922, the nectar flow from black locust occurred during the last week in May, thus coming after the tulip-tree nectar flow, instead of before. June also furnished either nectar or honeydew, and a slight amount of nectar was available in September. No data are available as to pollen yields.

In the case of each colony, brood rearing in the spring of 1920 was begun first in the second hive body. A check to brood rearing took place during the cold weather of April in both the packed and unpacked colonies. Inasmuch as the method of direct counting necessitated keeping the frames out of the hive for a considerable time, thus creating a disturbance to the colony lasting over several hours, much brood must have suffered undue exposure, a fact which in itself would account for any check at this time, even though other data are not available. In colony E this check is not so evident, owing to natural requiring during this period. In May, in each case, before the maximum was reached incoming nectar gave a check to brood rearing, while the brood nest was being maintained in the second hive body only, sufficient bees not being on hand to engage in brood-rearing activity in the lower hive body. Consumption of this fresh nectar soon made more room available in the second hive body, and the continued emergence of bees so enlarged the colony population that possession was taken of the lower hive body for brood-rearing purposes. Only one super was given to any colony, this being provided on May 21. In each colony the maximum brood-rearing activity of the season was reached shortly afterwards. During the last week in August no records were taken, a fact which accounts for the gaps in the curves at that time.

Colony A (fig. 19 and Table 18), after the initial check to brood expansion in April, proceeded at a fairly rapid rate to its maximum. This was not attained until after the close of the tuliptree nectar flow. A rapid decline then ensued, lasting through June, probably first brought on by incoming nectar, but later accentuated by the fact that the queen was confined to the lower hive body by a queen excluder from June 9 to June 30. She was given the freedom of both hive bodies during the first two weeks of July, and a slight increase in brood-rearing activity took place. The dearth of nectar and pollen during the remainder of July brought on a further decline. On August 11 the super was removed. A slight increase in the brood-rearing rate was made in September at the time of the usual fall nectar flow. The queen was lost during the first week of October. A virgin queen was then reared and mated successfully, but too late to produce much brood before winter. The maximum brood rearing in this colony took place about a month too late for ideal conditions, and brood rearing just before the period of final contraction was not sufficiently great to afford an ideal number of young bees for winter.

Colony B (fig. 20 and Table 19), after the checks of April and May, attained its maximum in early June, following which there was a slight decline due to incoming nectar. A recovery made in the latter part of the month was followed by the midseasonal decline. On July 9 the queen was confined to the lower hive body, and on August 12 the super was removed. A somewhat pronounced response was made to the fall nectar flow.

Colony C (fig. 21 and Table 20) did less in brood rearing than any of the other colonies. The maximum rate was reached late in May. The midseasonal decline is not so sharp as in the case of the other

colonies; in fact, a rate nearly equal to the maximum was maintained throughout June. On July 19 the queen was confined to the lower hive body. Little response was made to the fall nectar flow. The brood-rearing activity of this colony did not augur well either for surplus or strength for winter.

Colony D (fig. 22 and Table 21) is the only other of the 1920 colonies comparable to colony A. It underwent the checks to brood rearing in April and May before reaching its maximum at the beginning of June. Colony A had reared more brood during this time than had colony D. Brood rearing in colony D, as in colony A, suffered a decrease immediately after the maximum. On July 7 the queen was confined to the lower hive body, was allowed the freedom of the second hive body on July 13, but was again confined to the lower hive body on July 20. Throughout the remainder of the season the brood nest was in the lower hive body. On August 10 the super was removed. During the last week of August the old queen was superseded. The combination of a new queen and the fall nectar flow caused a rather large increase in brood-rearing activity during September.

Colony E (fig. 23 and Table 22) lost its queen in early spring and a laying queen was introduced, the result being a condition somewhat equivalent to an early spring supersedure. The giving of a laying queen undoubtedly made the break in continuity of brood rearing shorter than would have resulted had it been necessary to wait for the mating of a virgin queen so early in the year. Even so, the colony did not reach its maximum brood-rearing activity until the second week in June. A decline ensued, the sharpness of which indicates a restriction due to incoming nectar. A rather slight recovery was made during the last week of June, followed in turn by a sharp decline. On July 2 the queen was confined to the lower hive body; was given access to the second hive body again on July 10, but on July 16 was confined to the lower hive body once more, where she remained for the rest of the season. On August 13 the super was removed. This colony made little response to the fall nectar flow.

In none of the five colonies did the initial expansion proceed without a check. The maximum brood-rearing activity of the season was reached too late to be of greatest value during the main honey flow, which, in the vicinity of Washington, D. C., usually occurs in May. With the possible exception of colonies B and C, in none of the colonies did brood rearing become so active just prior to the final contraction as to insure the number of young bees needed for good wintering conditions. As in the curves for 1921 (figs. 1 to 16), so in the curves for 1920 (figs. 19 to 23) there is shown a tendency for brood-rearing activity in the vicinity of Washington to reach its maximum during the fore part of the active season; this is succeeded in turn by a midseasonal decline broken more or less by incoming pollen or nectar. This decline is usually checked somewhat during the latter part of the active season by an abundant pollen yield in August and a nectar flow in September. Thus, barring differences due to variation in seasons, strength of colonies, and certain other factors within the hives which would cause in different colonies a variation in the responses even to identical stimuli during the same year, the general character of brood-rearing activity in the colonies under observation in 1920 is strikingly similar to that of brood-rearing activity in the colonies under observation in 1921 and 1922.

MIGRATIONS OF THE QUEEN WITHIN THE HIVE

Besides the study of brood-rearing activity in the colony as a whole throughout the year, it is of interest to follow the brood-rearing activity of the same colony within particular hive bodies during that period, because, if adequate room is provided, one hive body is rarely the scene of the brood rearing of a normal colony throughout an entire season. The existence of such a piece of apiary apparatus as a queen excluder suggests how common an occurrence it is for the queen to transfer her egg-laying activity from one hive body to another. The causes of these vertical migrations and the ultimate effects on brood-rearing activity are as yet not fully determined. In passing, another type of migration should be noted, which takes place entirely within a hive body and which may be termed a horizontal migration, or a migration from frame to frame. A knowledge of the causes and effects of the queen's migrations is of direct value in the determination of the size of frame and hive which will most directly contribute to a maximum brood-rearing activity.

Since, all things considered, colony No. 4 was the most normal of the 16, the migrations of its queen in 1921 (Fig. 24) and 1922 (Fig. 25) will be considered somewhat at length. The cluster of this colony during the winter preceding each of the two active seasons was located in the second hive body. It is probably because of this fact that brood rearing began there each spring. During the initial expansion of each year, however, the queen approached the limit of cells available in the second hive body, whereupon the lower hive body afforded the only room for an enlargement of the brood area, because the first super had not then been added.

In 1921, the season with inclement weather in April, there was comparatively little brood-rearing activity in the first hive body at any time. Such weather tends to contract the area occupied by the bees, and thus restrict the expansion of the brood area. These conditions, prevailing at the time of the queen's first visit to the lower hive body, naturally caused her stay there to be rather brief. When the weather became better more room was already available in the second hive body, owing in part to a further consumption of stores. This additional space allowed the queen to increase her egg-laying activities without much enlargement of the brood area in the first hive body which resulted from her initial visit. Furthermore, almost immediately afterwards, in May, nectar began to come in rather abundantly and was deposited in the third hive body, which had now been put on, the presence of nectar in this super attracting the queen upward rather than downward. In the meantime the first hive body became well filled with pollen and nectar. It is interesting to note that in the latter part of April, in response to the inclement weather, the sealed brood curve for the second hive body (Fig. 24) remains near a certain level until the effects of the bad weather have ceased, and that in the first hive body this curve does not rise above the point marking its first appearance. In 1922 (Fig. 25) the inclement weather occurred before the colony was in need of expanding into the lower hive body. The queen was therefore able to complete her stay below, and the sealed brood area in the first hive body came to occupy nearly as many cells at the end of April as had the brood area in the second hive body at the time of the expansion into the first.

The appearance of nectar in quantity in the third hive body is marked by migrations of the queen back and forth between the second and third hive bodies, her activity in the first dwindling away completely. In both seasons, by the beginning of the tulip-tree nectar flow the queen was at work in the third hive body, undoubtedly having been drawn there by the presence of large numbers of bees and incoming nectar, as well as having found so many cells in the other hive bodies filled either with brood, nectar, or pollen. On each return to the second hive body she found deposited there much pollen and some nectar. Each season these migrations produced three clearly defined peaks of brood rearing in the third hive body. Owing to the fact that between these peaks nectar was being crowded as closely as possible around the brood area, even in the cells from which bees had emerged, the queen was restricted continuously in room for egg laying. As a result, each successive peak in the third hive body became smaller and in the end no eggs were to be found above the second.

With the advent of the period of lessened brood-rearing activity in July, there was little incentive in either year for the queen to wander out of the second hive body. During the same period much of the honey and pollen in this hive body was consumed, with the result that at the beginning of increased brood-rearing activity during the latter part of the major period, caused by incoming pollen, there was sufficient room for a much larger expansion of the brood nest within this hive body than would be apt to take place at that time of year. This condition continued until the fall nectar flow, when the lateness of the season and possibly the slowness of the honey flow caused all incoming nectar to be deposited in the second hive body, around the outer edge of the brood nest or within it. The brood nest was then rapidly constricted by the moving of honey towards the center of the second hive body from both the first and third.

Since in none of the other colonies were conditions such as to induce vertical migrations to such an extent as in colony No. 4, general conclusions are not in order at this time. When all space in the second hive body became filled with brood or stores, the queen in colony No. 4 went below because there was no other place to go, and the population of the colony was already sufficiently great to be using the lower hive body. As the season progressed and a super was added and occupied the queen went up into the third hive body also, where there were so many bees and so much fresh nectar. At no time did she show signs of deserting the second hive body; and, when forced out of the third hive body by nectar and kept out of the first hive body by pollen and nectar, she confined her activity to the second hive body for the remainder of the season.

Although vertical migrations in brood-rearing activity were not carried to so extreme a degree by the other colonies as by colony No. 4, migrations did occur between the first and second hive bodies. In the case of the other colonies whose maximum brood-rearing activity came later in the season, consumption of stores had made more room available in the second hive body at the time of the need for the maximum room than was the case with colony No. 4, which needed room early. There was therefore not the need for expanding the brood area into another hive body to such a degree as in colony No. 4. Without exception, however, each colony did maintain more

or less of a brood area in the lower hive body during some portion of the season, and, in addition, colony No. 11 even made some use of the third hive body. In certain instances where much room was available in the second hive body horizontal migrations were found to exist. Whether vertical or horizontal, the peaks of brood rearing represented by these migrations are separated roughly by 3-week intervals, or the time necessary for brood to develop.

Statements to the effect that the queen hesitates to cross from one hive body to another are often found in the literature of beekeeping. As far as colony No. 4 (figs. 24 and 25) is concerned, there is no indication of any such hesitancy. It may be well to remember in this connection that Langstroth hive bodies were used in the experiment and that good worker combs were present. The curves at no point suggest that any of the breaks are due to a hesitancy in the transference of egg-laying activity from one hive body to another; in fact, the sharpest rise in colony No. 4 during 1922 is accompanied by such a transfer with no resulting break. This holds true of other parts of the curve for the same colony in 1922 as well as 1921. It would seem, then, that the queen will readily ascend or descend from one hive body to another if the intenseness of brood-rearing activity necessitates more room, provided worker bees have taken possession of the other hive body either because of activities in connection with nectar gathering or because of an overflow population.

COMPACTNESS OF BROOD NEST

In spite of any migration of the queen within the hive, a study of the location of the sealed brood (figs. 26, 27, 28, and 29) throughout the active season shows a remarkable compactness in the brood area. At all times of the season, except at about the time of the final contraction, the brood area of colony No. 4 occupied contiguous frames in the second hive body. The most apparent exception occurred during the final contraction in 1921, when the brood area in the second hive body became divided by combs which were filled entirely with honey. The same compactness is observable in the areas occupied in the first and third hive bodies, the only noteworthy exception being in 1922. In that year one of the frames in the third hive body became completely filled with nectar before the queen had occupied the frame on either side. When the brood area had included the frame next to this frame of honey, the queen passed around the full comb and laid eggs in the frame on the other side. For several weeks the brood area in the third hive body was thus divided. Whenever the brood area crossed the limits of the second hive body into the first and third, this expansion took place almost entirely in territory as adjacent as possible to the second hive body. This is not apparent from the figures, because for each side of any frame the bar represents by its length the size of the sealed brood area in proportion to the total surface of each side of that frame, represented by the vertical dimension of the frame, and not the exact location of the sealed brood on that frame. Hence the sealed brood in each frame is represented diagrammatically as being in the center of that frame. In the figures only sealed brood is represented, while the present discussion refers to the compactness of all brood.

The location of the sealed brood through both years brings out also the persistency of the brood area. By persistency of the brood area is meant a tendency to rear brood in the cells which have already been occupied by brood, and a tendency for any expansion in the brood area to take place only in cells on frames immediately adjacent to those already thus occupied. In each spring the area of sealed brood was expanded rapidly, but during any expansion the area first used for brood rearing was kept occupied for that purpose. The rapid increase in the number of cells on each frame occupied by brood is just as striking as is the increase in the number of frames used. The first relinquishment of any part of the brood area for any purpose other than brood rearing was due to encroaching nectar. Throughout both years the second hive body maintained its predominance as the center of brood-rearing activity, even though at times the queen carried on extensive egg-laying activity in the other hive bodies.

TIME RELATION OF BROOD REARING TO NECTAR GATHERED

It was pointed out at the beginning of this bulletin that the honey crop may be reduced (1) by an insufficient number of worker bees, (2) by a consumption of surplus honey by bees reared out of season, or (3) by swarming induced by a congestion of bees in the brood nest. Because colony No. 4 stored more honey than any of the other 15, and because its brood-rearing activity during 1921 presented features more ideal for the region of Washington than did the others, only this colony will be discussed in detail from the standpoint of the time relation of brood rearing to nectar gathered.

Although in 1921 the maximum of sealed brood in colony No. 4 came in conjunction with the height of the honey flow, the honey gathered during the main honey flow was not wastefully consumed by bees emerging later in the season, as the maximum field force was available to take advantage of an intense yield of honeydew. The maintenance for this large force during the summer was therefore provided through the efforts of the colony itself. In the season of 1922, although the actual maximum of sealed brood came a week late and a rate of emerging bees nearly equal to the maximum was maintained during part of the honey flow, the maximum rate had been nearly reached during the week prior to the peak. A creditable showing was therefore made, three supers being actually used for storing nectar, as stated earlier, whereas in 1921 one less super was given for this purpose.

A swarming impulse was scarcely noticeable during either 1921 or 1922 in any of the colonies under observation. A few queen cells were started; following the prompt removal of these no further preparations for swarming were observed. In none of the colonies, however, was the queen allowed to be so restricted in egg laying at any one time as to result in any significant reduction in the actual number of young bees needed to care for larvæ or perform other hive duties. This point is of importance because the presence of an overabundance of young bees has been held one cause of swarming. Demuth (7, p. 13) has stated: "The fact that the tendency to swarm is greatest at about the time the bees are rearing the greatest amount of brood has led to the belief that swarming is caused by the presence in the hive of a large proportion of young bees not yet old enough for field work." But, since under normal conditions bees not of field age perform duties inside the hive, it would seem that the mere

presence of bees too young for field work does not in itself induce swarming unless there is such an excess of young bees beyond those required for hive duties as to interfere with the routine of the colony.

Any appreciable excess of young bees arises, not for the sake of intensifying the natural swarming impulse, but rather as a result of other factors. Such an excess is bound to occur if conditions within the colony prevent a large number of young bees from performing the functions of their normal life cycle. This would be the case whenever brood-rearing activity reached the limit of cells available at a period when the brood-rearing area would have been further enlarged if more cells had been at hand, or if under similar conditions brood rearing were restricted through a reduction in the number of cells available for brood by their use for incoming nectar or pollen. The egg-laying rate being then reduced to a noticeable extent for several days, there would eventually be fewer larvæ to care for, fewer cells to clean out, fewer cells to be sealed over, and a diminution in all of the activities incident to a period of intense brood rearing. In consequence, since such duties are usually performed by young bees, there would be many of the latter out of a job, so to speak.

Throughout the observations in this research it has been noted that all colonies, strong as well as weak, tend to crowd incoming nectar not only around the border of the brood nest but even within the brood area itself whenever an empty cell is found. Such a tendency has long been recognized. Consequently, if during a honey flow many cells within the brood area proper become available for depositing incoming nectar through the emergence of large numbers of young bees, the queen may be restricted suddenly in her activity, as happened in 1921 to the queen in colony No. 4. Under these conditions there would result an excess of young bees. Whether this excess would be large enough to induce swarming would depend on the degree and duration of restriction of the queen's activities. In the case of colony No. 4 and the others the restriction was never of long duration. It has often been observed that just prior to swarming the queen almost entirely ceases egg laying, so that all unsealed brood disappears. Such a condition is simply the natural result if any large number of brood cells have been used for another purpose. Not only may the number of cells available for egg laying become insufficient through diversion to use for incoming nectar and pollen, but even without any reduction in number by these causes there will be too few whenever brood rearing itself reaches the limit of cells available in the hive. During a period of normal seasonal increase in brood-rearing activity, idle field bees may at times cause a congestion within the hive which apparently interferes with brood rearing. Any of these conditions may arise independently of any honey flow, and would tend to explain the fact that swarming is not always correlated with a honey flow.

In the colonies under discussion a swarming impulse was doubtless restrained by the fact that at no time was any colony crowded for room long enough to cause a serious break in the continuity of brood rearing at a time when the tendency toward brood-rearing activity was strong. Whenever any queen became restricted in any particular hive body during a period favorable to continued, heightened brood-rearing activity, she was able to migrate to a more suitable region within the hive. Through this ability to transfer her activity else-

where the queen was able to maintain an egg-laying rate which was normal in its response to the varying stimuli of the season as modified by the condition of the colony itself. Thus in these colonies the possibility of the occurrence of such a large excess of idle young bees as would be conducive to swarming was reduced to a minimum, a fact which may account largely for the absence of any indication of a swarming impulse in either season.

EGG LAYING

From the counts of sealed brood (Tables 1 to 17), the maximum daily egg-laying average over a 12-day period has been calculated for each of these colonies, 12 days being the average time represented by sealed worker brood. Any daily average derived from sealed brood is not to be interpreted as representing the actual daily egg-laying performance of the queen bees in question, since it has long been recognized that a queen bee lays more eggs than ever develop into adults. This excess of eggs is often very evident in spring, becoming less apparent during maximum brood-rearing activity, and again becoming evident in the fall. The constant seasonal correlation found in the weekly counts of sealed brood throughout the years covered by this investigation shows, however, that a reliable index to seasonal brood-rearing activity may be obtained by counts of sealed brood. Since the success of brood-rearing activity is to be gauged by the number of adult bees reared, it is evident that this is more closely determined from counts of sealed brood than from any other type of brood count.

In neither season did the queen in colony No. 4 approach any such a daily egg-laying rate as that found by Von Berlepsch (3) in his experiment. The same holds true of the other 15 colonies studied in 1921. The highest daily average during any 12-day period, as derived from the counts of sealed brood, was found to be 1,587, and represents the performance of the queen in colony No. 4 in 1922, her highest similar rate in 1921 being 1,488. Of the other colonies in 1921, colony No. 14 had a maximum daily rate of 1,513. Five colonies (Nos. 2, 6, 11, 15, and 16) show maximum daily rates between 1,250 and 1,400, while the similar rates of six (Nos. 1, 5, 9, 10, 12 and 13) were between 1,000 and 1,250. In 1921 the maximum daily average of each of the 1919 queens is below 1,000. The time relations between maximum brood-rearing activity and nectar flows or pollen yields have already been discussed for each colony. The queen in colony No. 12, even in September, shortly after first beginning to lay, attained a daily average of 905.

In the colonies studied in 1920 an egg-laying rate of over 1,500 per day was attained in only one colony, the queen in colony A averaging 1,528 eggs per day for one 21-day period. In colony D, in the same year, the queen attained a maximum daily rate of 1,468 eggs for one 21-day period, and the maximum daily egg-laying rates of the queens in colonies E, B, and C for any 21-day period were 1,223, 1,201, and 1,008, respectively. These daily averages may be compared with Dufour's (11) maximum daily average of 1,627 during any 21-day period. On the other hand, Baldensperger (1), in his estimates already referred to, gives 2,600 as a daily average for a period of 23 days. It must be remembered, however, that Baldensperger's method is not adapted for strictly accurate scientific results. Of the

daily egg-laying rates found by Brännich (6) even the highest is slightly below 2,000. In fact, he states his belief that a daily rate of 2,000 eggs has never been exceeded in any of his colonies.

At the end of his article already referred to, Dufour (11) makes a statement which applies with equal effect to the colonies used in this work. Although he recognizes that the egg-laying rates which he publishes are only averages and, as such were undoubtedly exceeded at times, he justly asserts that the results of his work do not warrant the assumption that any such daily egg-laying rates as 3,000 or more had ever been reached in any of the colonies used in his experiments. Since the daily egg-laying average for any season is far below the daily egg-laying average for any particular number of days within the maximum of that season, it is readily seen that the remarkably high rates of egg laying over short periods, so often published in beekeeping literature, can not be used as the daily averages for an entire season.

CONCLUSIONS

In this work no special effort has been made to modify the time of the various phases of brood rearing or to increase their intensity other than to provide adequate stores and ample room at most times; the colonies were therefore in much the same condition as might be found in an average apiary. The following conclusions may be drawn from the records of brood rearing presented here:

The number of bees in the colony at the beginning of brood rearing in the spring, the ability of the queen, the abundance of stores, the suitability of the combs and proper insulation are the most important factors within the control of the beekeeper which determine the amount of brood reared by a colony.

The seasonal brood cycle in any region is marked by certain definite phases—the initial expansion, the major period, and the final contraction. These tend to remain constant from year to year, their normal occurrence and magnitude being determined to a large degree by local weather conditions and by the local honey flows and pollen yields.

A strong colony tends to retain its strength from year to year, other things being equal.

A queen at times transfers her egg-laying activity from one hive body to another, without any appreciable diminution in her rate of egg-laying if the combs are good.

The possibility of young bees occurring to such an excess as to be conducive to swarming is reduced if the queen has ready access to another hive body, in case egg laying in the one already occupied becomes restricted through incoming pollen, nectar, or brood-rearing activity.

Every colony used in 1921 shows a migration of the queen from one hive body to another, from which it may be inferred that if only one hive body had been available the amount of brood reared would have been reduced.

There is a decided tendency for the brood area of the colony to be confined to adjacent combs in one or more hive bodies in such a way as to maintain the brood area in compact form.

Although it can not be concluded from this investigation that the use of old queens is always disastrous, the records show that their use is accompanied with risk.

Prolonged inclement weather retards brood rearing in the spring, although a strong colony may be able to maintain its rate through unfavorable cold weather of only a few days' duration, even though it is not packed.

During the latter part of the active season the beekeeper may make important preparations for the next year's honey crop by providing any of the factors which are necessary for the unrestricted increase of brood rearing during the period of initial expansion. Among the most important of these for every colony are good stores in sufficient quantity to last until incoming nectar suffices in the next active season, a good queen, and an abundance of worker comb. Although some of these conditions might be provided in the spring, any postponement is dangerous. Such preparations during the preceding active season, together with any others necessary for good wintering, may be expected to result in increased brood rearing so early in spring as to have the largest field force of the season available during the nectar flow instead of after it has passed.

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TABLES

TABLE 1.—Record of sealed brood in colony No. 1 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 16	4,871	May 9	11,090	July 5	10,786	Aug. 29	5,484
21	7,858	16	11,601	11	10,134	Sept. 6	4,655
28	9,713	23	11,596	18	9,152	12	4,563
Apr. 4	10,100	31	12,322	25	7,319	19	4,012
11	11,260	June 6	11,256	Aug. 1	6,939	26	5,410
18	10,140	13	10,731	8	6,139	Oct. 3	4,485
25	9,500	20	10,970	15	5,898	10	1,772
May 2	10,412	27	11,148	22	6,175	17	401

TABLE 2.—Record of sealed brood in colony No. 2 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 16	5,821	May 11	13,551	July 6	9,489	Aug. 31	6,543
23	11,438	18	13,178	13	9,853	Sept. 7	4,908
31	12,212	25	12,873	20	13,613	14	4,920
Apr. 6	13,366	June 1	13,352	27	11,849	21	7,196
13	13,067	8	14,068	Aug. 3	10,271	28	6,008
20	9,867	15	14,693	10	9,587	Oct. 5	2,156
27	10,822	22	15,399	17	7,649	12	569
May 4	12,814	29	15,787	24	7,591	19	473

TABLE 3.—Record of sealed brood in colony No. 3 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 17	4,355	May 19	10,821	July 14	5,626	Sept. 8	1,098
25	8,795	26	4,711	21	5,013	15	5,843
31	10,414	June 2	3,184	28	4,432	22	9,582
Apr. 7	11,339	9	4,928	Aug. 4	3,272	29	4,940
14	9,736	16	6,297	11	2,214	Oct. 6	2,756
21	8,667	23	6,804	18	1,832	13	1,859
28	10,543	30	6,794	25	¹ 1,639	20	708
May 5	11,743	July 7	6,177	Sept. 1	1,472	26	265
13	11,614						

¹ Supersedure.

TABLE 4.—Record of sealed brood in colony No. 4 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 16	5,012	May 10	16,982	July 5	13,659	Aug. 30	8,898
23	9,024	17	17,859	12	11,741	Sept. 6	9,448
29	11,186	24	17,155	19	11,084	13	8,015
Apr. 5	12,327	31	10,955	26	9,904	20	7,862
12	14,781	June 7	13,079	Aug. 2	8,204	27	9,433
19	15,402	14	12,408	9	7,840	Oct. 4	7,644
26	14,072	21	13,674	16	7,459	11	3,973
May 3	15,028	28	14,588	23	7,871	18	1,143

TABLE 5.—Record of sealed brood in colony No. 5 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	4, 187	May 11	8, 134	July 6	11, 502	Aug. 31	5, 043
23	4, 919	18	8, 763	13	10, 224	Sept. 7	1, 640
30	3, 949	25	11, 047	20	8, 669	14	2, 121
Apr. 6	3, 696	June 1	12, 277	27	6, 168	21	3, 300
13	4, 662	8	12, 830	Aug. 3	4, 571	28	3, 652
20	4, 940	15	12, 567	10	3, 803	Oct. 5	1, 372
27	5, 765	22	13, 062	17	4, 187	12	
May 6	8, 949	29	12, 405	24	7, 267		

TABLE 6.—Record of sealed brood in colony No. 6 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	5, 702	May 9	14, 829	July 5	13, 313	Aug. 29	6, 029
21	7, 593	16	15, 592	11	11, 870	Sept. 6	4, 856
28	9, 415	23	16, 211	18	12, 679	12	6, 686
Apr. 4	9, 120	31	16, 401	25	12, 554	19	7, 818
11	11, 536	June 6	14, 130	Aug. 1	11, 048	26	7, 871
18	12, 976	13	11, 893	8	9, 369	Oct. 3	4, 694
25	12, 772	20	13, 304	15	8, 296	10	945
May 2	14, 497	27	14, 690	22	7, 584		

TABLE 7.—Record of sealed brood in colony No. 7 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 17	4, 914	May 10	9, 923	July 12	2, 496	Sept. 13	9, 769
22	8, 308	17	10, 319	19	2, 015	20	10, 849
29	10, 332	24	9, 232	26	1, 253	27	5, 888
Apr. 5	10, 904	June 1	7, 558	Aug. 2	996	Oct. 4	4, 492
12	11, 149	7	7, 348	9	659	11	3, 066
19	10, 050	14	6, 977	16	454	18	669
26	10, 531	21	5, 436	23	338		
May 3	10, 887	28	3, 650	30	1, 127		
6	10, 417	July 5	2, 354	Sept. 6	2, 873		

¹ Supersedure.

TABLE 8.—Record of sealed brood in colony No. 8 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 16	4, 241	May 19	8, 768	July 21	6, 411	Sept. 22	1, 014
25	7, 092	26	8, 070	28	6, 154	29	4, 380
31	7, 650	June 2	7, 591	Aug. 4	5, 856	Oct. 6	4, 147
Apr. 7	8, 504	9	7, 669	11	5, 390	13	⁵ 1, 152
14	8, 542	16	6, 402	18	5, 614	20	⁽⁶⁾
21	7, 623	23	6, 338	25	¹ 2, 685	26	520
28	8, 091	30	6, 711	Sept. 1	(2)	Nov. 3	2, 075
May 5	8, 825	July 7	6, 410	8	(3)	10	1, 136
14	9, 088	14	6, 507	15	(4)		

¹ Supersedure.² Virgin lost.³ Requenced.⁴ New queen laying.⁵ Queenless, requenced.⁶ New queen laying.

TABLE 9.—Record of sealed brood in colony No. 9 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 17	6,397	May 9	11,245	July 5	11,375	Aug. 29	18,274 ¹
21	8,337	16	11,421	11	10,789	Sept. 6	5,851
28	8,686	23	11,670	18	10,331	12	7,842
Apr. 4	8,443	31	11,638	25	10,199	19	9,004
11	10,297	June 6	11,408	Aug. 1	10,549	26	8,703
18	10,951	13	10,620	8	10,015	Oct. 3	5,831
25	11,536	20	10,744	15	9,854	10	2,350
May 2	12,223	27	11,521	22	9,961	17	197

¹ Supersedure.

TABLE 10.—Record of sealed brood in colony No. 10 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 23	8,196	May 18	12,352	July 13	10,878	Sept. 7	6,936
31	10,218	25	12,119	20	9,645	14	6,603
Apr. 6	10,985	June 2	11,276	27	8,661	21	8,241
13	12,392	8	10,717	Aug. 3	4,191	28	8,675
21	12,886	15	11,294	10	(¹)	Oct. 5	5,677
27	12,103	22	11,758	17	-----	12	3,165
May 4	11,434	29	11,745	24	2,188	19	907
13	12,242	July 6	11,376	31	6,102	25	695

¹ Natural requeening.

TABLE 11.—Record of sealed brood in colony No. 11 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 17	6,475	May 14	15,580	July 7	12,928	Sept. 1	7,281
25	12,283	19	15,414	14	11,840	8	4,388
31	13,788	26	16,227	21	10,847	15	5,294
Apr. 7	16,134	June 2	14,678	28	10,914	22	7,699
14	15,712	9	10,855	Aug. 4	10,658	29	7,804
21	12,837	16	14,916	11	9,406	Oct. 6	4,661
28	12,388	23	15,205	18	9,687	13	1,231
May 5	14,585	30	15,054	25	9,731		

TABLE 12.—Record of sealed brood in colony No. 12 during the season of 1921, by weeks

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	5,904	May 17	9,930	July 19	9,213	Sept. 20	5,557
22	7,417	24	11,651	26	8,289	27	(²)
29	9,328	June 1	12,095	Aug. 2	4,675	Oct. 4	-----
Apr. 5	11,017	7	11,156	9	2,768	11	316
12	12,913	14	10,276	16	2,042	18	657
19	13,229	21	10,335	23	1,202	26	497
26	12,855	28	10,500	30	1,372	Nov. 1	162
May 5	12,682	July 5	13,520	Sept. 6	5,295		
10	10,718	12	9,897	13	10,871		

¹ Supersedure.² Natural requeening.

TABLE 13.—*Record of sealed brood in colony No. 13 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	3,404	May 13	10,783	July 8	12,680	Sept. 2	8,564
25	6,728	20	12,684	15	11,681	9	8,313
Apr. 1	8,291	27	13,220	22	11,605	16	9,511
8	9,444	June 3	13,256	29	9,871	23	10,134
15	10,533	10	14,752	Aug. 5	4,648	30	6,891
22	9,724	17	12,234	12	(¹)	Oct. 7	3,655
29	8,705	24	12,732	19	-----	14	1,431
May 6	9,768	July 1	12,745	26	4,141	21	379

¹ Natural requeening.TABLE 14.—*Record of sealed brood in colony No. 14 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	9,101	May 13	12,018	July 8	16,098	Sept. 2	11,404
25	12,412	20	14,106	15	15,463	9	7,597
Apr. 1	11,732	27	16,479	22	14,281	16	7,404
8	12,856	June 3	17,175	29	11,889	23	9,436
15	12,527	10	17,414	Aug. 5	12,299	30	5,180
22	9,995	17	18,162	12	12,929	Oct. 7	1,757
29	9,545	24	18,151	19	13,126	14	963
May 6	12,012	July 1	16,779	26	13,446	21	192

TABLE 15.—*Record of sealed brood in colony No. 15 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	6,514	May 13	8,425	July 8	13,949	Sept. 2	6,976
25	8,225	20	12,957	15	12,017	9	2,489
Apr. 1	8,469	27	15,608	22	12,293	16	4,311
8	11,605	June 3	15,545	29	10,907	23	8,240
15	9,938	10	15,555	Aug. 5	8,969	30	2,929
22	7,794	17	15,625	12	7,846		
29	8,531	24	16,080	19	9,119		
May 6	11,214	July 1	15,239	26	10,467		

TABLE 16.—*Record of sealed brood in colony No. 16 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	6,654	May 13	8,719	July 8	12,686	Sept. 2	(¹)
25	12,034	20	13,043	15	8,423	9	3,586
Apr. 1	13,778	27	13,974	22	10,485	16	8,555
8	12,259	June 3	12,914	29	8,914	23	6,304
15	12,949	10	14,383	Aug. 5	8,036	30	2,987
22	5,461	17	15,845	12	6,744	Oct. 7	1,701
29	3,632	24	13,397	19	3,449	14	131
May 6	6,009	July 1	11,115	26	48		

¹ Natural requeening.

TABLE 17.—*Record of sealed brood in colony No. 4 during the season of 1922, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 10	3, 190	May 12	18, 694	July 14	10, 494	Sept. 15	8, 519
17	5, 521	19	18, 661	21	9, 597	22	8, 395
24	6, 125	26	17, 301	28	8, 703	29	8, 870
31	6, 435	June 2	16, 204	Aug. 4	8, 321	Oct. 6	6, 102
Apr. 7	9, 831	9	14, 457	11	8, 523	13	3, 756
14	14, 372	16	13, 658	18	8, 872	20	2, 986
21	17, 096	23	14, 154	25	10, 177	27	1, 183
28	18, 755	30	13, 942	Sept. 1	10, 548		
May 5	19, 049	July 7	12, 614	8	9, 649		

TABLE 18.—*Record of brood in colony A during the season of 1920, by weeks*

Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells
Mar. 15	2, 842	May 28	32, 092	Aug. 4	15, 343	Oct. 13	(²)
22	3, 206	June 2	30, 466	11	14, 472	20	2, 065
29	7, 748	16	28, 530	18	14, 253	27	3, 493
Apr. 6	15, 686	24	23, 886	25	(¹)	Nov. 3	3, 519
14	11, 101	30	20, 611	Sept. 2	12, 562	10	3, 273
21	16, 622	July 8	19, 153	9	10, 311	18	1, 601
28	21, 160	14	19, 713	15	8, 939	24	860
May 3	25, 895	21	19, 034	22	9, 585		
12	30, 421	28	18, 347	29	6, 489		
19	30, 258		16, 527	Oct. 6	3, 340		

¹ No record taken.² Natural requeening.TABLE 19.—*Record of brood in colony B during the season of 1920, by weeks*

Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells
Mar. 10	1, 894	May 13	16, 656	July 15	17, 774	Sept. 16	9, 000
15	1, 338	20	19, 683	22	17, 799	23	10, 703
22	1, 542	27	24, 370	29	16, 358	30	12, 341
29	5, 060	June 3	25, 231	Aug. 5	14, 102	Oct. 7	6, 986
Apr. 7	8, 239	10	23, 314	12	12, 894	14	3, 417
15	5, 983	17	23, 349	19	12, 835	21	1, 275
22	9, 093	25	25, 255	26	(¹)	28	864
29	12, 595	July 1	23, 927	Sept. 3	10, 452	Nov. 4	331
May 4	15, 461	9	18, 884	10	7, 968		

¹ No record taken.TABLE 20.—*Record of brood in colony C during the season of 1920, by weeks*

Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells
Mar. 17	2, 609	May 17	18, 051	July 19	16, 873	Sept. 20	9, 866
24	3, 497	24	20, 194	26	16, 090	27	8, 572
31	7, 159	29	21, 177	Aug. 2	15, 422	Oct. 4	7, 613
Apr. 7	8, 261	June 7	19, 536	9	15, 428	11	4, 394
13	8, 692	14	19, 150	16	16, 446	18	1, 995
19	8, 655	22	18, 678	23	(¹)	25	824
26	12, 024	28	19, 346	31	14, 031	Nov. 1	155
May 5	17, 894	July 6	19, 198	Sept. 7	10, 525		
10	16, 626	12	18, 331	13	9, 761		

¹ No record taken.

TABLE 21.—*Record of brood in colony D during the season of 1920, by weeks*

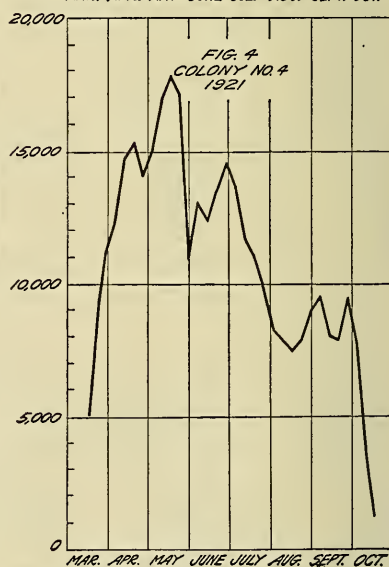
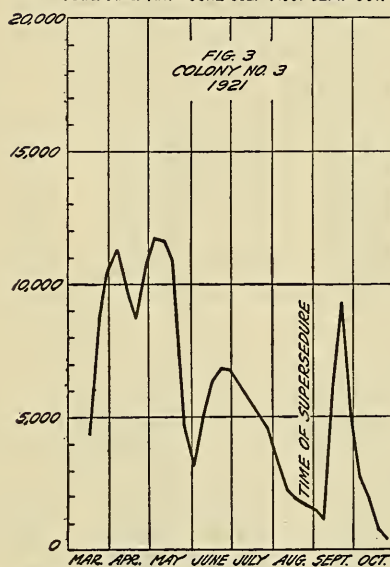
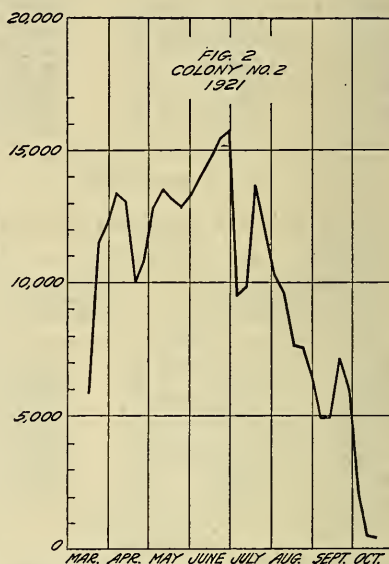
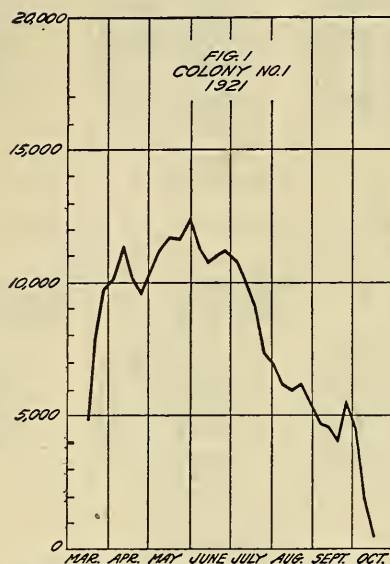
Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells
Mar. 17	3,397	May 18	23,382	July 20	20,910	Sept. 21	11,519
24	4,987	25	29,411	27	18,022	28	15,016
31	10,222	June 1	30,840	Aug. 3	19,347	Oct. 5	10,779
Apr. 7	13,374	8	29,059	10	18,631	12	6,976
13	11,466	15	28,019	17	19,189	19	4,650
20	12,564	23	26,556	24	(¹)	26	3,223
27	18,691	29	26,431	Sept. 1	² 7,536	Nov. 2	633
May 6	24,788	July 7	21,777	8	3,234		
11	25,157	13	20,822	14	7,120		

¹ No record taken.² Supersedure.TABLE 22.—*Record of brood in colony E during the season of 1920, by weeks*

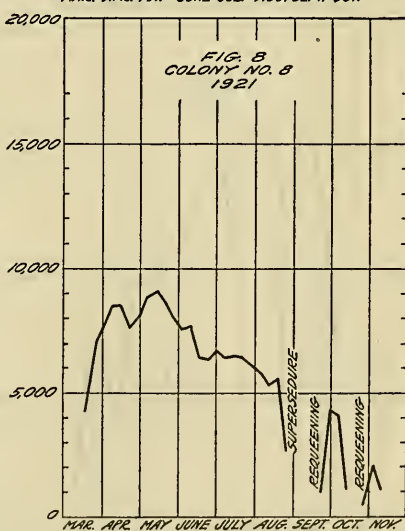
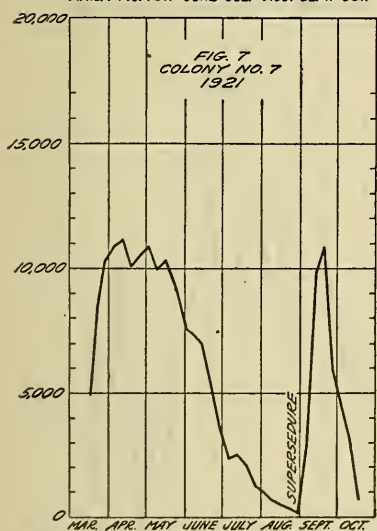
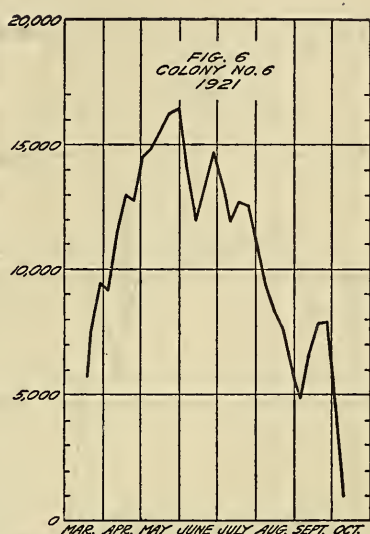
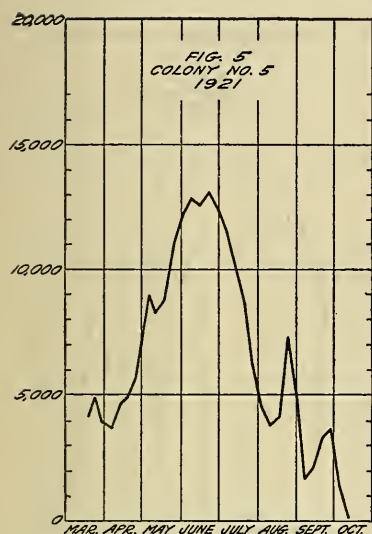
Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells
Mar. 17	1,037	May 21	19,546	July 23	13,190	Sept. 24	8,384
24	1,567	28	22,398	30	10,686	Oct. 1	8,918
31	4,897	June 4	23,523	Aug. 6	11,809	8	6,182
Apr. 8	6,078	11	25,685	13	12,826	15	4,652
15	(¹)	18	22,250	21	12,519	22	2,877
23	6,458	26	21,706	28	(²)	29	1,304
30	11,255	July 2	22,469	Sept. 4	12,251		
May 7	14,821	10	22,077	11	9,330		
14	15,537	16	18,077	17	8,426		

¹ Requeening.² No record taken.

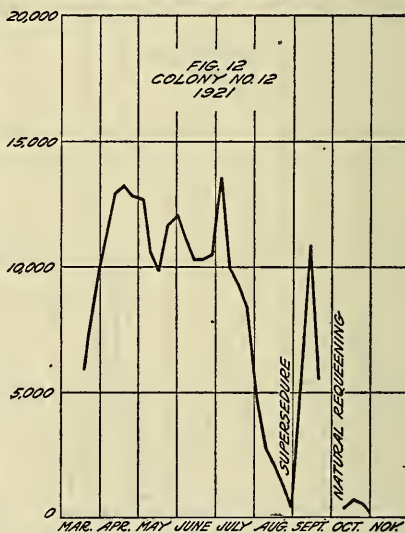
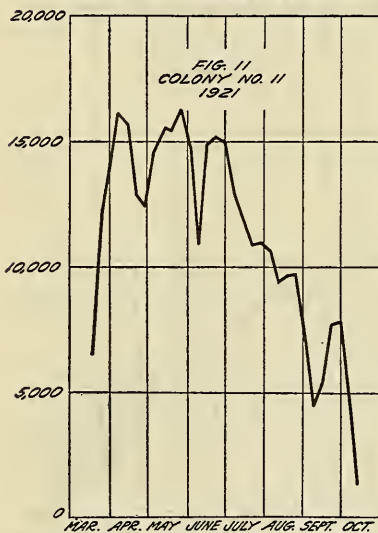
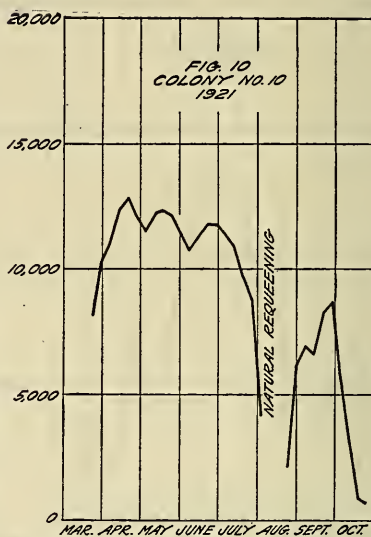
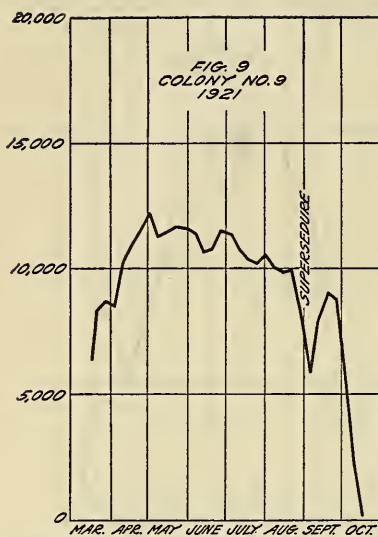
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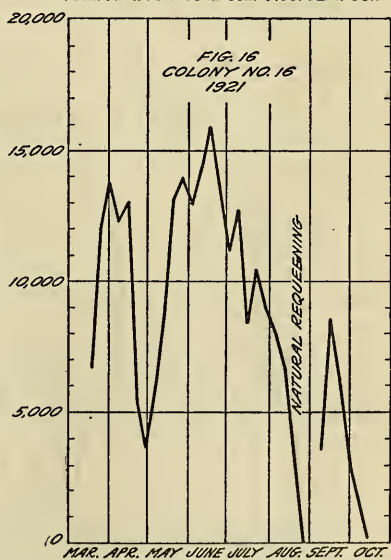
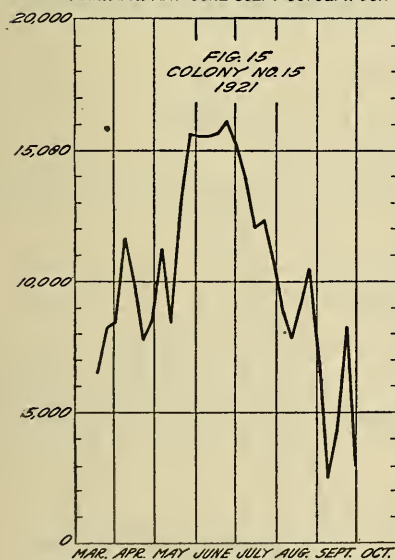
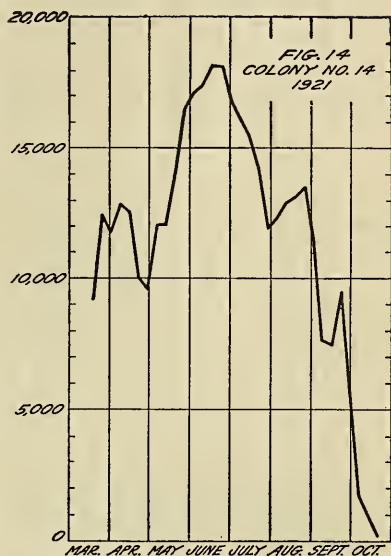
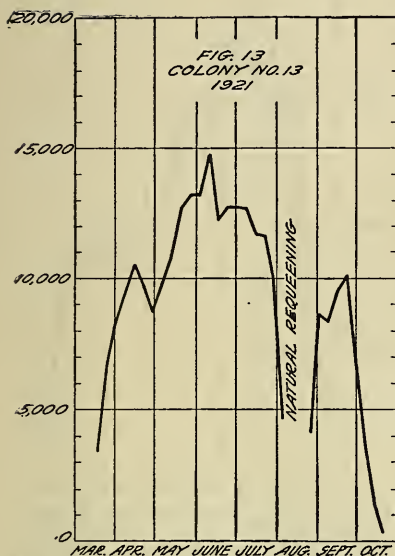
FIGS. 1 to 4.—Curves showing amount of sealed brood found weekly during the season of 1921 in colonies Nos. 1 to 4



FIGS. 5 to 8.—Curves showing amount of sealed brood found weekly during the season of 1921 in colonies Nos. 5 to 8



FIGS. 9 to 12.—Curves showing amount of sealed brood found weekly during the season of 1921 in colonies Nos. 9 to 12



FIGS. 13 to 16.—Curves showing amount of sealed brood found weekly during the season of 1921 in colonies Nos. 13 to 16

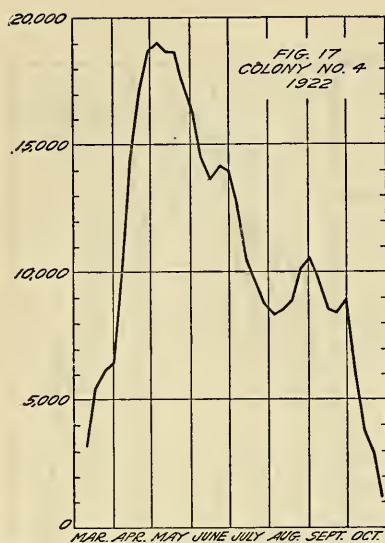


FIG. 17.—Curve showing amount of sealed brood found weekly during the season of 1922 in colony No. 4

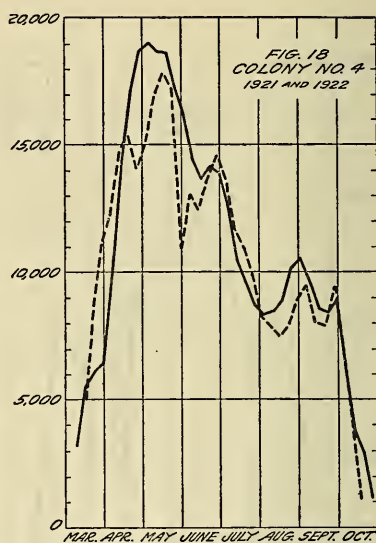
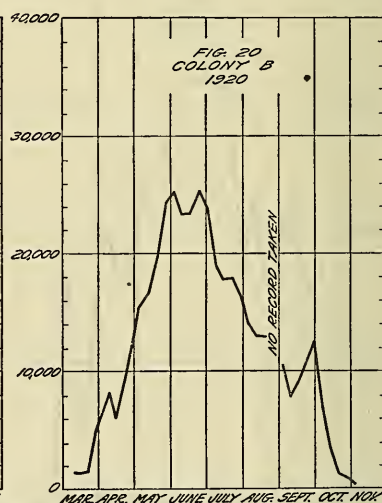
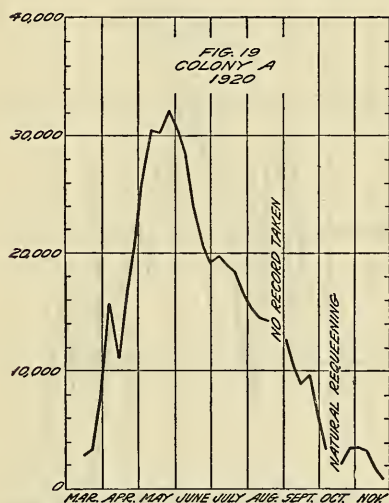


FIG. 18.—Curves showing amount of sealed brood found weekly during the seasons of 1921 and 1922 in colony No. 4. The curve for 1921 is represented by a broken line; that for 1922 by an unbroken line



FIGS. 19 and 20.—Curves showing total eggs, unsealed larvae, and sealed brood found weekly during the season of 1920 in colonies A and B

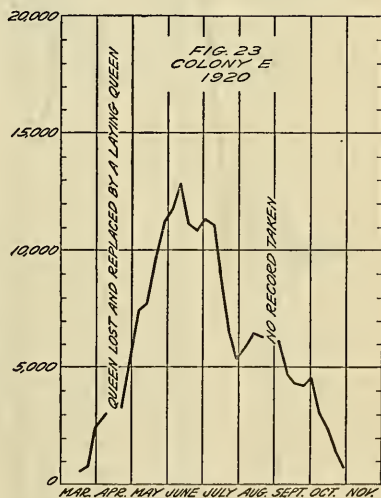
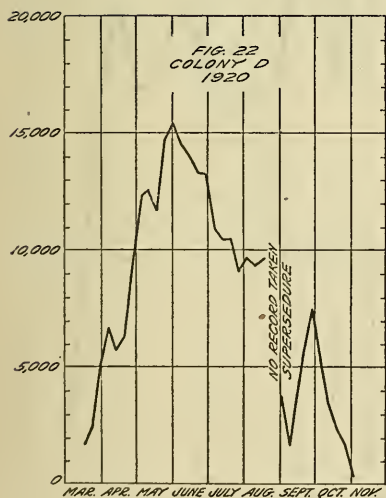
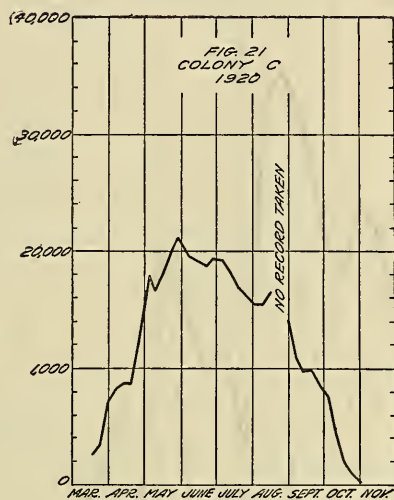
United States Department of Agriculture

Department Bulletin 1349,

"The Brood-Rearing Cycle of the Honeybee."

Correction Slip

Page 49, figs. 21 to 23. The numbers at the left of the horizontal lines in the graphs should be the same as in Figures 19 and 20, page 48, namely, 40,000, 30,000, 20,000, 10,000 and 0.



FIGS. 21 to 23.—Curves showing total eggs, unsealed larvæ, and sealed brood found weekly during the season of 1920 in colonies C, D, and E

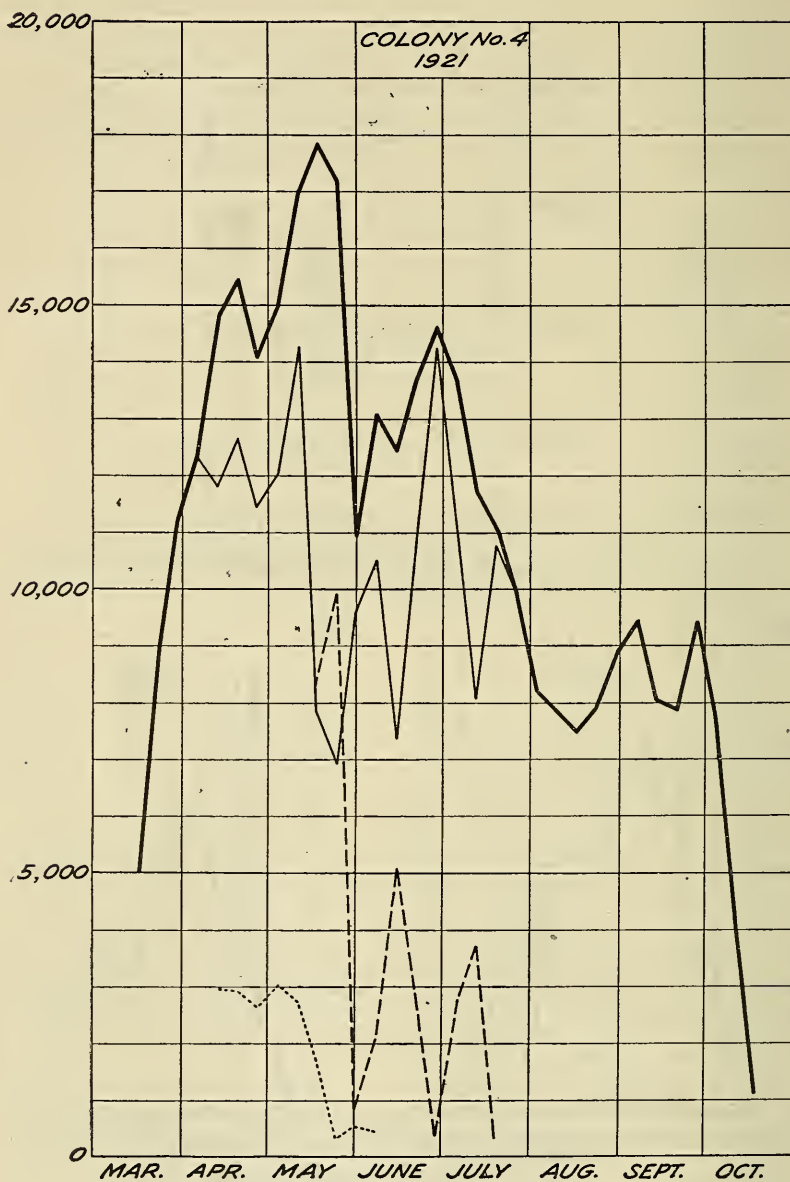


FIG. 24.—Curves showing amount of sealed brood found weekly in the various hive bodies during the season of 1921 in colony No. 4. The heavy unbroken line represents the total of all hive bodies; the dotted line the first, the narrow unbroken line the second, and the narrow broken line the third hive body

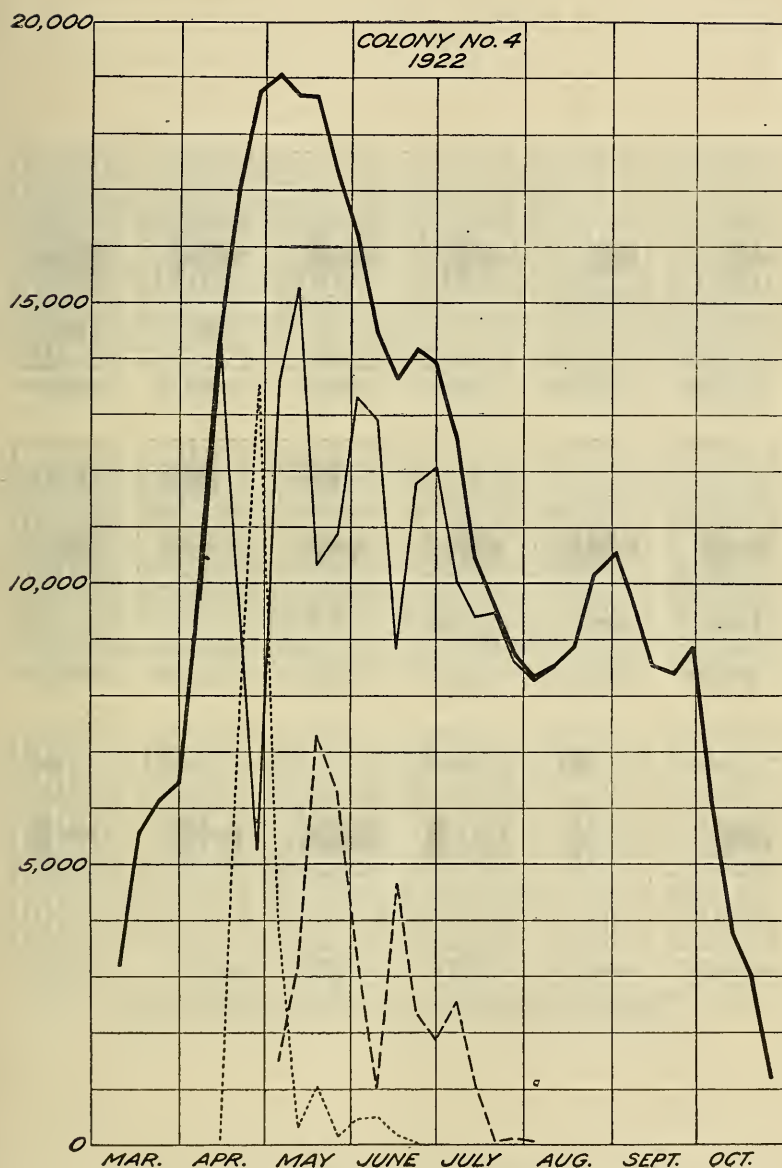


FIG. 25.—Curves showing variation in sealed brood found weekly in the various hive bodies during the season of 1922 in colony No. 4. The heavy unbroken line represents the total of all hive bodies; the dotted line the first, the narrow unbroken line the second, and the narrow broken line the third hive body

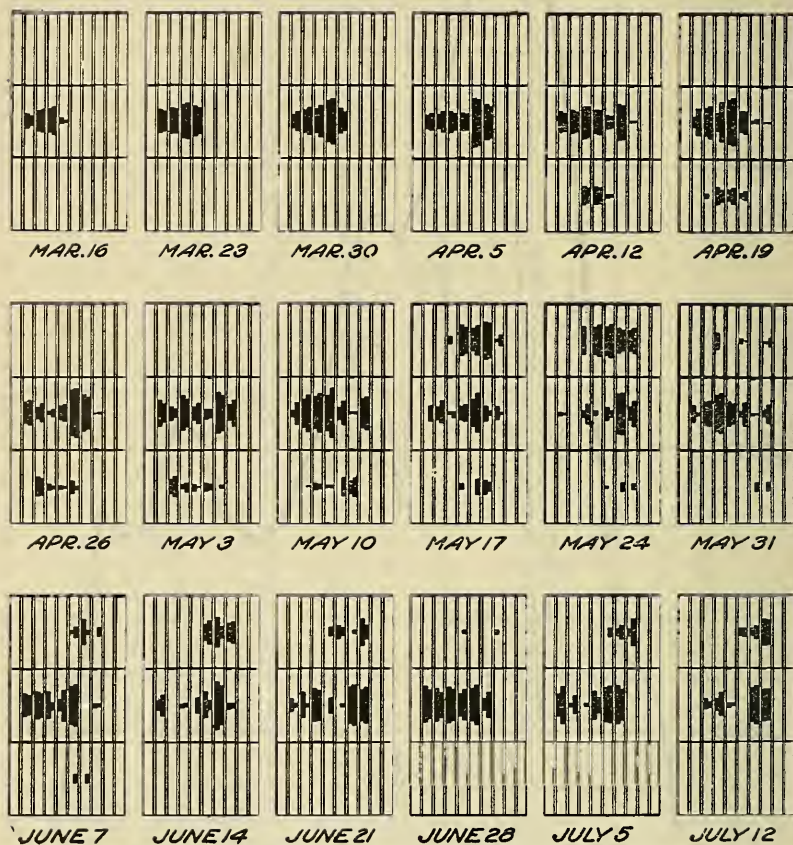


FIG. 26.—Diagrammatic representation of the amount of sealed brood on each side of each frame in the three hive bodies of colony No. 4 from March 16 to July 12, 1921

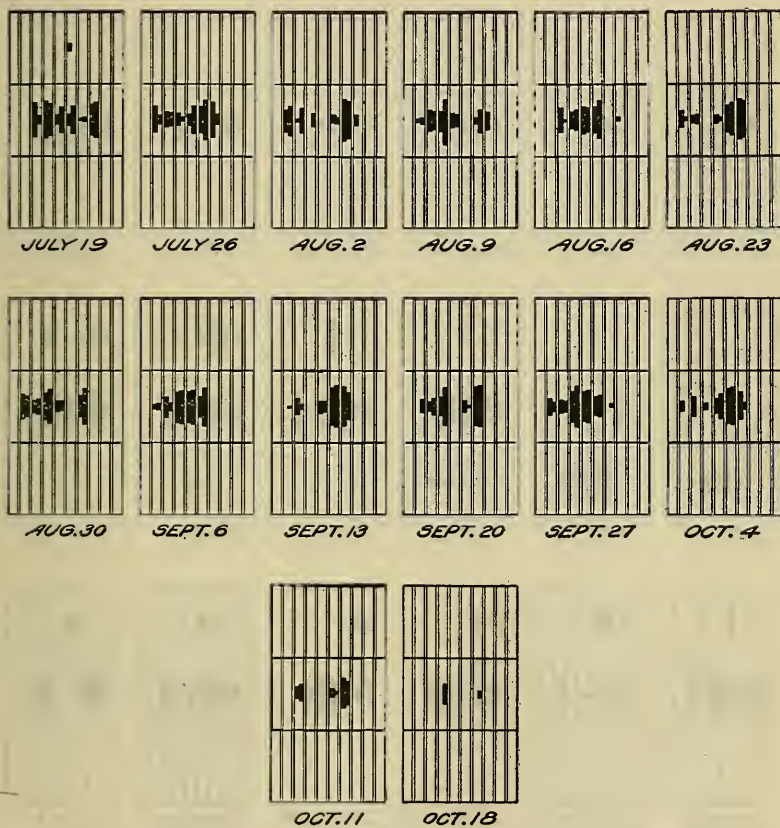


FIG. 27.—Diagrammatic representation of the amount of sealed brood on each side of each frame in the three hive bodies of colony No. 4 from July 19 to October 18, 1921

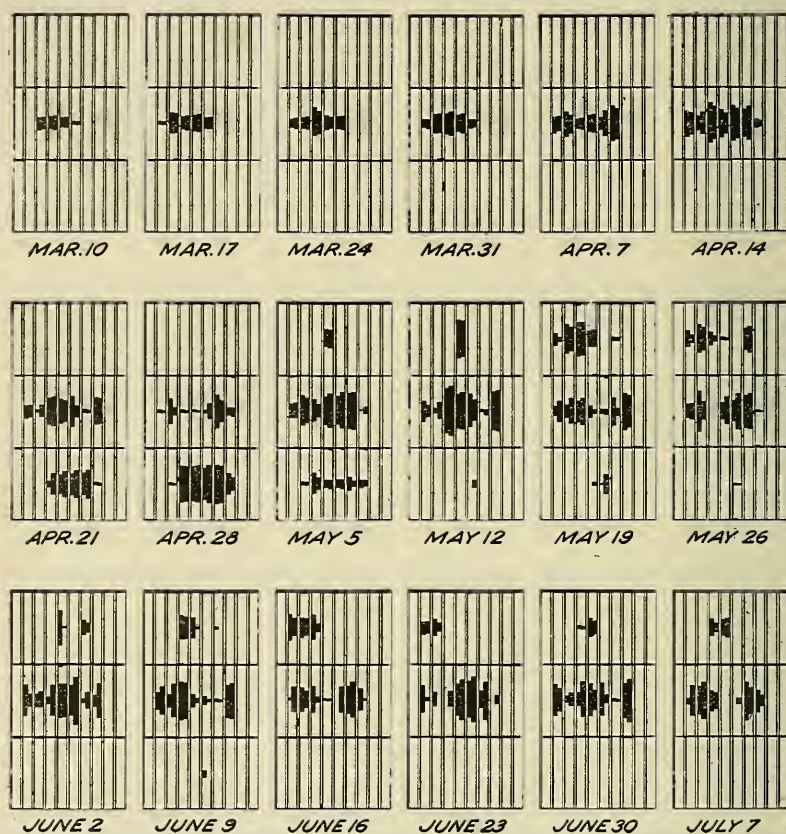


FIG. 25.—Diagrammatic representation of the amount of sealed brood on each side of each frame in the three hive bodies of colony No. 4 from March 10 to July 7, 1922

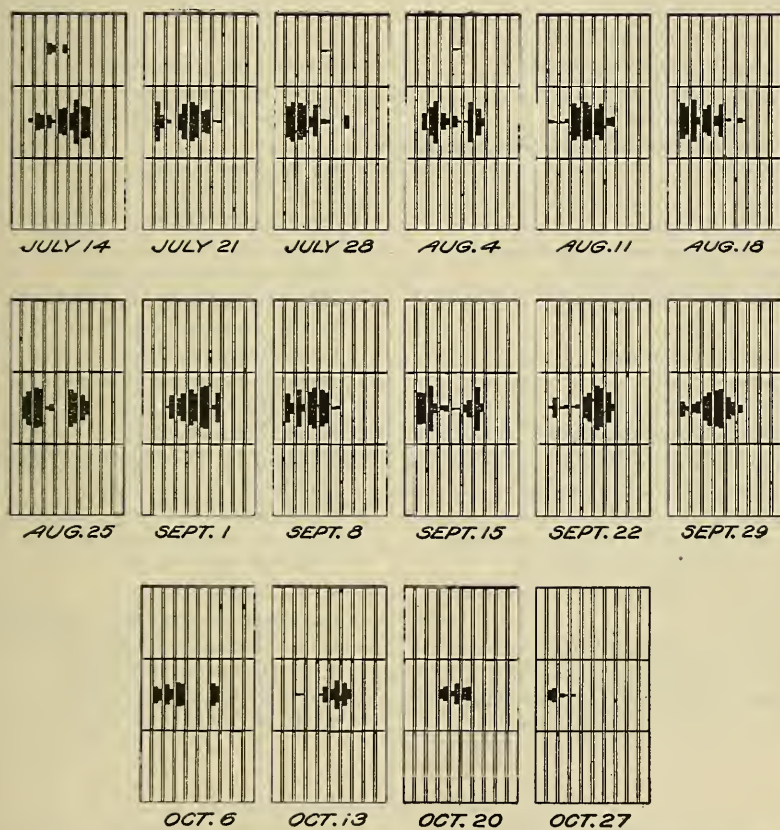


FIG. 29.—Diagrammatic representation of the amount of sealed brood on each side of each frame in the three hive bodies of colony No. 4 from July 14 to October 27, 1922

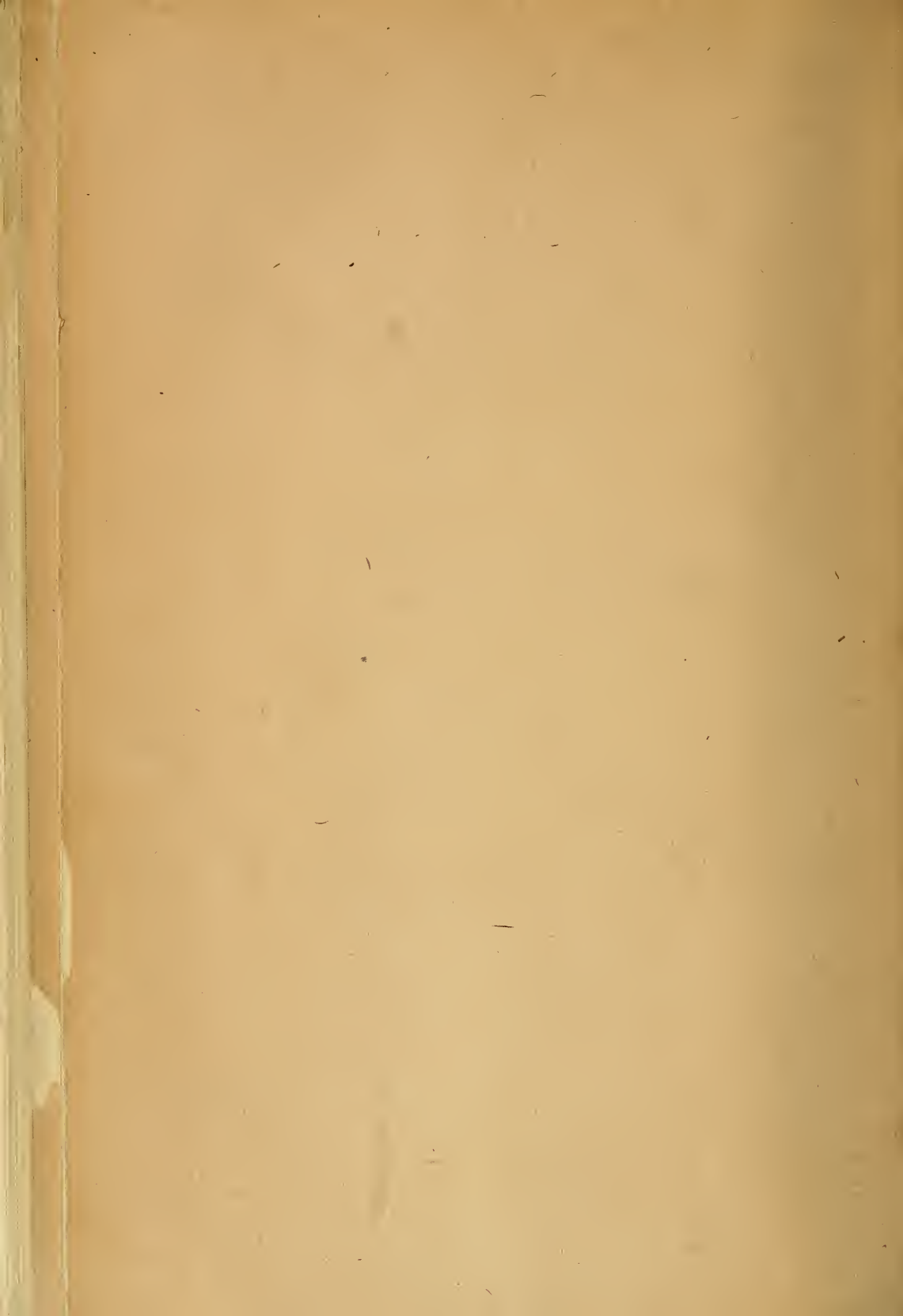
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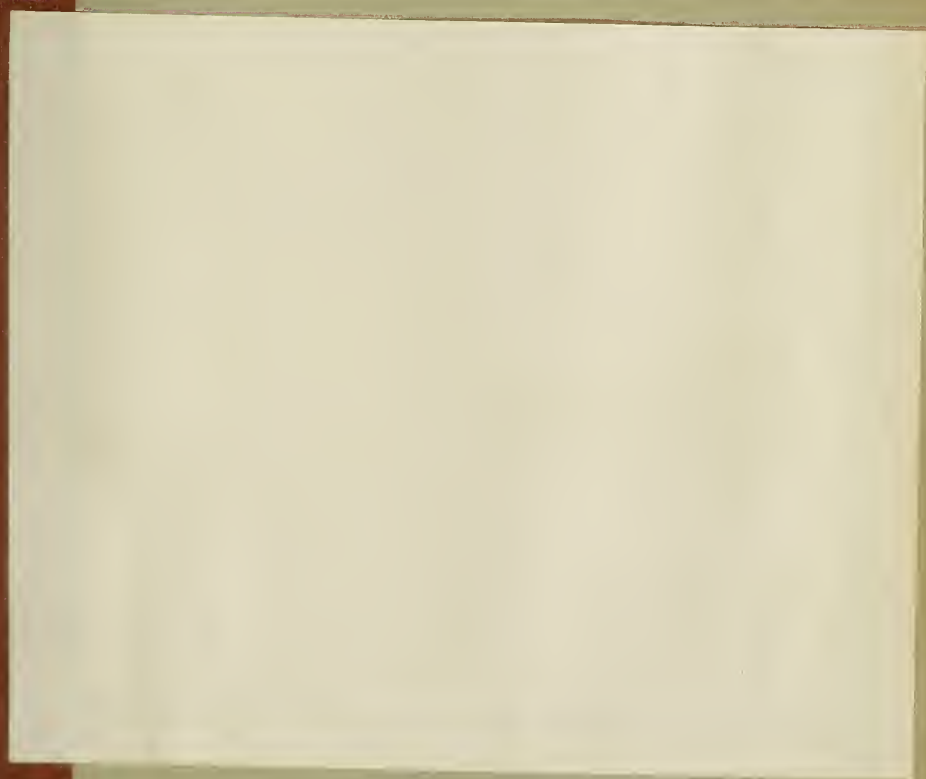
September 8, 1925

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<i>Division of Bee Culture Investigations</i> ---	J. I. HAMBLETON, <i>Apiculturist, in Charge</i> .







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